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Founded by J. A. Nieuwland, C.S.C.

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The Hungarian Partridge in Wisconsin

Robert A. McCabe[1] and Arthur S. Hawkins[2]

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Introduction

The Hungarian partridge (*Perdix perdix*) in Wisconsin has never reached the densities expected by those who were responsible for its introduction. In 1935 the Department of Wildlife Management at the University of Wisconsin with the cooperation of twelve farmers owning adjoining farms at Lake Mills,

1 Biologist, University of Wisconsin Arboretum, Madison, Wisconsin.
2 Game Technician, Illinois Natural History Survey, Urbana, Illinois.

Wisconsin, first attempted to manage Hungarian partridges, with the main purpose of raising the local population. These dozen farms are known as the Faville Grove Area. After six years of cover planting, winter feeding, and the prohibiting of partridge hunting, the partridges did not increase and did not even maintain their early densities. In short, our local partridge management failed.

We did, however, learn something of the partridge's population behavior and of its life history in Wisconsin, and have established some criteria of age, all of which are described in this paper. These studies were made in Jefferson county on two areas: 2500 acres at the Faville Grove Area, and a 32,000 acre tract surrounding Faville Grove, called the "big area" in this paper.

Hawkins conducted the studies for the years 1935-38, McCabe from 1940-43. Semiannual censuses were made yearly; nesting studies, yearly through 1942 with the exception of 1939.

ACKNOWLEDGMENTS

Appreciation is expressed to Professor Aldo Leopold, under whose guidance this study was made, for assistance throughout the research period and for editing the manuscript. Also to Joseph J. Hickey and F. N. Hamerstrom, Jr., of the University of Michigan for critical reading of the manuscript; William Rowan of the University of Alberta for supplying information on the Hungarian partridge in Canada; Raymond D. Owen of the University of Wisconsin for aid in sexing of embryos and preparation of photomicrographic material; Lyle K. Sowls, H. R. Siegler and Irven O. Buss for help with the field work; James Zupke for assistance with pen rearing of partridge chicks; others who contributed advice and guidance: R. K. Meyer, Wm. H. Elder, J. M. Torrie, Alice Harper and Virginia Kiesel of the University of Wisconsin, A. S. Leopold and A. H. Miller of the University of California; Marie S. McCabe for many hours of typing and advice in manuscript revisions.

Appreciation and thanks are likewise extended to the Wisconsin Conservation Department for donating young partridges to the study and for allowing us to examine the state game farm birds.

The Status of the Hungarian Partridge in Wisconsin

The range of the Hungarian partridge in Wisconsin comprises twenty southeastern counties. The land varies from flat to rolling and lies mostly in the glaciated region of the state. The main soil types are silt loam, prairie, and peat, with red clay areas along Lake Michigan to the north. The land is largely given over to diversified farming and dairying. The farm units are comparatively small, averaging about 140 acres. Superficially, the landscape resembles much of the Hungarian partridge range of central Europe.

The Hungarian partridge was first introduced into Wisconsin in 1908 by Colonel Gustav Pabst of Milwaukee, and subsequent plantings were made by him through 1929. These partridges were obtained from Central Europe (Bohemia) and the subspecies is in all probability *perdix*. The birds were released in one-thousand lots in Ottawa township of Waukesha County and totalled about five thousand. Leopold (1940: 6)states that the established populations of the state originate, with minor exceptions, from these plantings. Other private plantings and those of the State Conservation Department bring the total number of Hungarian partridges planted in Wisconsin to date (1946) to 6,470.

The spread from the Pabst releases was very slow, and today nowhere

exceeds 125 miles from the site of the initial release. A detailed account of this spread up to 1937 is given by Leopold (1940:7) and the contour lines of Figure 1 illustrate the spread rate. The recent spread occurred toward the north (Green Lake County) where the soil is similar to that of the southern counties. There was no spread in the sand counties to the northwest. The aversion to sand is illustrated in southwestern Columbia County where the spread "mushroomed" against the southern border of the sandy area, spreading westward into Sauk county along the border of the sandy soils. There is as yet little spread into the driftless area of western Dane and other southwestern counties.

In addition to the main range in the southeast, a 1943 survey by McCabe revealed small isolated populations in Polk, St. Croix, and Buffalo counties which border on the Mississippi River in the northwestern part of the state. These birds have stemmed from one, or both, of two sources: local plantings,

Fig. 1.—Spread of the Hungarian partridge during four successive periods. The spot where partridges were originally liberated is labelled "Pabst Plantings." The areas where these studies were made appear in northwestern Jefferson county.

or eastward drift from the Minnesota plantings. Another small isolated population in Outagamie county is known to stem from local plantings.

During the same year that Colonel Pabst made the original planting in Wisconsin, a group of sportsmen led by Fred J. Green introduced the Hungarian partridge into Canada at Calgary, Alberta. The extent to which the Canadian birds have surpassed the Wisconsin birds both in apparent numbers and spread rate is shown in Table 1. Although we have no census figures for the Canadian provinces, the spread rate was 28 miles per year compared with 5 miles per year for Wisconsin.

The total Wisconsin kill reports of licensed hunters since 1932 (first year compiled) are shown in Table 2. The number of birds killed is indeed small,

TABLE 1.—History of the Hungarian Partridge in Wisconsin and Alberta, Canada.

	Wisconsin	*Alberta*
Initial planting	1908	1908
Total number of birds planted	6470	800 (175 pairs in original plant)[1]
Chief location	Waukesha County	Calgary
First open season	1919	1913[2]
First open season, area	2 counties	Vicinity of Calgary[3]
Longest open season	21 days (1939)	92 days (1934)
Largest bag limit	4 birds per day (1939)	15 birds per day; 200 per season (1933)
Spread rate	5 miles per year	28 miles per year[4]
Land use	Diversified farming, units small	Wheat raising, units large
Best yearly kill	50,478 (1939)	No records

1 Seth Gordon (1935:2). William Rowan writes that the initial planting was 175 pairs (communication).

2 William Rowan (communication) gives 1913 as first open season; T. S. Palmer *et al.*, (1915: 36).

3 Inference from A. M. Fordyce (1932:124).

4 Aldo Leopold (1932:80).

TABLE 2.—Hungarian Partridge Kill of Wisconsin Hunters.

Year	Sq. Mi. Open	Kill	Kill per Sq. Mi.
1932	1161	6,348	5.5
1933	1161	6,095	5.2
1934	3463	6,356	1.8
1935	4134	8,326	2.0
1936	3833	11,549	3.0
1937	5272	10,187	1.9
1938	5541	18,292	3.3
1939	6849	26,248	3.8
1940	6255	19,541	3.1
1941	6523	10,547	1.6
1942	8373	11,506	1.4
1943	5939	3,053	.5
1944	5180	2,145	.4

but it will serve as an indicator to population trends. The kill-per-square-mile column may be slightly inaccurate since a county or more was opened to hunting when only a portion of the county had partridges. On an acreage basis the total kill would amount to 259 acres per bird killed per year. Racine county in 1938, where a bird was killed for every 54 acres, has the best record for any county. From 1932 through 1944, 3,085,249 hunting licenses have been purchased in Wisconsin, and the corrected[3] total kill of Hungarian partridges for that period is 310,305. These figures give an average of one bird killed annually per ten hunters during the 10-year period ending 1942.

The pheasant kill of 2,604,000 for the same area and period indicates that ten times as many pheasants were killed as partridges. This does not take into consideration that only cock pheasants are hunted. The pheasant kill during the 1941-42 season was 211 cocks for each partridge bagged. Thus the partridge is insignificant in the upland game bag and becoming even less prominent annually.

Jefferson County, in which our more detailed work was done, presents no better picture of Hungarian partridge populations than does the state when yearly hunting reports are analyzed. Table 3 presents the accumulated data.

Hungarian Partridge Range

RANGE IN THE NORTH CENTRAL STATES

The geographic range of the Hungarian partridge in the north central states appears to have changed very little since Leopold's survey in 1929 (1931: 107). In order to check the change in range since this time, we asked a qualified man in each north central state to map the range for that state. This information was generously given by the following:

Minnesota—Gustav Swanson, Assoc. Prof. of Economic Zoology, U. of Minn.
Iowa—Bruce F. Stiles, Chief, Div. of Fish and Game
Ohio—Frank E. Hart, Game Management Agent
Indiana—William B. Barnes, Pittman-Robertson Project Leader
Illinois—Ralph E. Yeatter, Game Specialist, Illinois Natural History Survey
Michigan—Fred Dale, Pittman-Robertson Project Leader (Pittman-Robertson Quarterly, vol. 1, no. 2, p. 156).

The data thus obtained were used to make a composite picture of the partridge range in the north central states, and we believe Fig. 2 to be the best available approximation of the range as of 1943.

Minnesota has had the greatest extension of range. In 1929 only a few counties bordering Iowa had an established partridge population; today all of the western and much of the central part of the state is populated. Wisconsin has had moderate range expansion (Figure 1), which has been discussed under an earlier caption. Other states have had little or no expansion.

What constitutes good Hungarian partridge habitat? The only visible feature is that open agricultural land is preferred habitat both in North America

3 The corrected total kill figure is obtained when the reported kill is raised proportionately to include those hunters not reporting. It is assumed that the proportion of game killed is the same for those reporting as for those not reporting.

and in England. Yet open agricultural land alone is no criterion of densities, for although England and Canada have high population densities (1 bird per 2 acres) their habitats are unlike in cover, agricultural practices, soils, size of farm units, game-management practices, and hunting pressure. The north central states are similar in many respects to both England and Canada, yet here the partridge densities are uniformly low (1 birds per 25 or more acres). If type of habitat determines density, it follows that there is something about the habitats of England and Canada that is lacking in the north central states.

Recently there have been indications that the center of the established Wisconsin range has fallen in density while the periphery has retained a fair density. To what extent this apparent "heart rot" is prevalent throughout Wisconsin is not known, but certain of the central sections, particularly large areas in Jefferson county, are now without partridges. This fact has become evident to conservation groups and state game officials for the counties in the center of the range (Fig. 1), namely Waukesha, Jefferson, Walworth, Racine and Kenosha. These have all been closed to partridge hunting for the past two seasons (1944 and 1945).

Fig. 2.—Range of the Hungarian partridge in the North Central states; crosses indicate isolated populations.

TABLE 3.—Jefferson County Hungarian Partridge Kill.

Year	BIRDS KILLED		Acres per Bird (corrected)	Hunting Licenses	Birds per Hunter (corrected)
	Uncorrected Returns	Corrected to 100%*			
1934	1296	2695	131	2871	0.9
1935	1812	4022	88	3070	1.3
1936	1518	2019	175	3310	0.7
1937	1754	2526	140	3495	0.7
1938	1718	2962	119	3854	0.8
1939	2392	4600	77	4443	1.1
1940	2204	4408	80	4273	1.1
1941	921	2649	133	4796	0.6
1942	1041	3589	98	3590	1.0
9-year Total	14,656	29,470		33,602	
9-year Average	1628	3274	116	3733	0.91

* Reported kill of the Jefferson county licensed hunters raised proportionately to include those not reporting. It is assumed that the proportion of game killed is the same for those reporting and those not reporting.

1943, 1944 and 1945 had no open season.

CLIMOGRAPHIC TEST OF RANGE

The effect of climate on an introduced species may often play a vital part in the establishment of that species in its new habitat and the densities attained by it.

The climograph (hythergraph) is a kind of chart which may be used to evaluate year-long temperature and precipitation as environmental factors. Twomey (1936: 124) uses the climograph to compare the climates of the native European range of the Hungarian partridge with those of various American ranges to which the bird was introduced. To construct a "standard" climograph representing the European range, he superimposed on each other various local climographs and then connected their extremities. The resulting polygon is assumed to represent the ranges of temperature and precipitation for areas in which the Hungarian partridge thrives. For further comparison we shall transpose the Twomey polygon for the European optimum to our climographs.

Climographs for five new areas were worked out: (1) Lake Mills, Wisconsin, (2) Blissfield, Michigan, (3) Defiance, Ohio, (4) Colfax, Washington, and (5) Edmonton, Alberta (Fig. 3). Temperature and precipitation are represented as monthly averages. The companion bar graph gives the sunshine averages for corresponding months.

Compared with the European optimum climatic conditions, Wisconsin, Michigan and Ohio show the critical months during which the chicks are raised, July and August, protruding outside the optimum. These three states have established populations which are existing at a very low level. In California, where partridges have failed (Cottam *et al.*, 1940: 6), the climate from

May through September is not only too warm but too dry. Washington has all months within the optimum figure, and according to Yocom (1943: 194) its partridge densities are high. Alberta has only the period from November through March protruding far outside the European optimum. According to all available information, Alberta has the highest Hungarian partridge population of any area compared. From these graphs it appears that winter departures which affect only adult birds are tolerated, but unless the summer extremes which affect the survival of the young fall within the Twomey polygon, the species either fails or does not thrive.

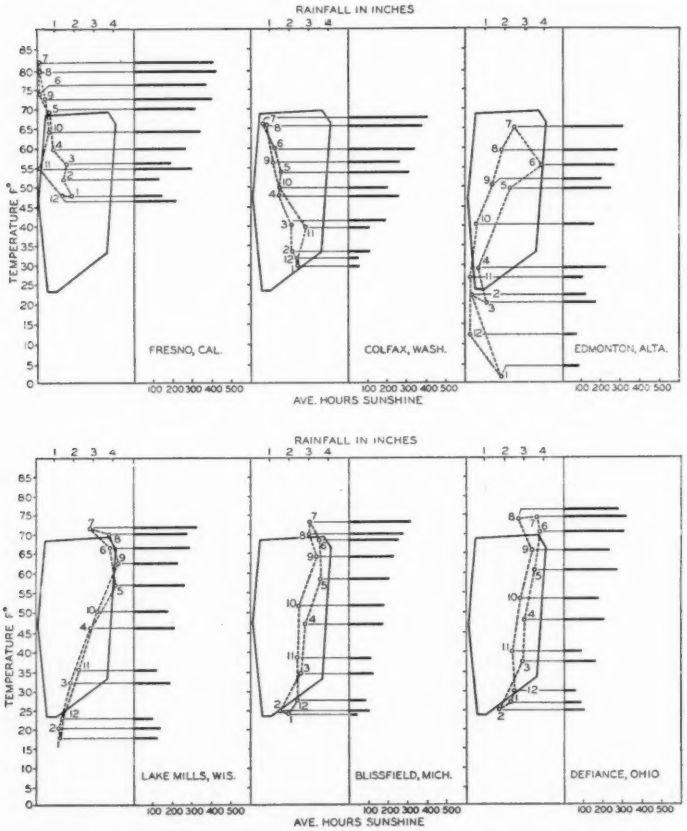

Fig. 3.—Climographs of six Hungarian partridge ranges in North America (broken lines) compared with the European optimum (solid polygon). The figures indicate months and the bars show hours of sunlight per month. The Fresno map is taken from Twomey (1936).

We were unable to evaluate effect of sunshine as an environmental factor affecting partridge populations, although the records make interesting comparisons. The average monthly sunshine* (in hours) for the areas graphed during the critical months are as follows:

	June	% of Possible	July	% of Possible	August	% of Possible
Lake Mills, Wisconsin	289	63	324	70	274	64
Blissfield, Michigan	261	57	293	57	314	73
Defiance, Ohio	306	67	327	71	286	66
Fresno, California	413	94	432	97	404	96
Colfax, Washington	342	72	405	91	365	83
Edmonton, Alberta	246	48	314	61	274	59

* No average is for less than 25 years.

The true effect of climate is often obscured by averages. Adverse climatic conditions become lethal in three ways, suddenness, severity, and duration, all of which may be absorbed in averages. Climatic conditions that in themselves would have no effect on wildlife may be combined to produce a climatic complex that is detrimental. For example, rain or temperatures just below freezing are of no importance separately, but a temperature drop to below freezing during a rain may cause serious food shortage by coating both food and grit with ice.

Despite averages, the climographs emphasize the facts that the climate in the north central United States does not conform to the European optimum during the nesting season of the partridge and that severe cold alone is not a limiting factor. We primarily attempted a detailed study of the nesting season in this paper.

A RECENT PARTRIDGE INTRODUCTION INTO TEXAS

The first practical test of the climograph in predicting range possibilities for the Hungarian partridge was offered in a recent Texas introduction.

In the latter part of 1942 Hawkins reported a contemplated Hungarian partridge release in the region of Amarillo, Texas. A climograph was made out at that time for this part of the Texas pandhandle (Figure 4.). A comparison of this climograph with our others reveals that the Texas panhandle, like the north central states, has an unfavorable nesting season since the months of June, July, and August lie well outside the European optimum, indicating that the area is too hot during the nesting season. Therefore our prediction was that if the initial plantings did "catch," the established population would be sparse with local fluctuations, as is the case in Wisconsin and Michigan.

In March, 1943, 100 pairs of wild trapped partridges sent from Alberta, Canada, were released 40 miles southwest of Amarillo in Deaf Smith County. The releases of 50 pairs each were made in two localities 29 miles apart. Some of the birds wandered as far as 14 miles in the first two months after their release. Five broods and two destroyed nests were found in 1943, so at least seven pairs nested. Hawkins, stationed at the army base in Amarillo, was in

close contact with the progress of the release and reported that at least 50 birds entered the winter.

In the spring of 1944 Mr. Gene Howe of the Texas Fish and Game Commission, who sponsored the introduction, offered a prize of $50 for the first brood seen, and although the prize went unclaimed a brood of three was said to have been raised about two miles from a release point. Hawkins last saw a pair on November 15, 1944. In the same area a brood of five was seen last spring. Five miles away another small brood was reported. These are the only reports for 1945. While the history of these Texas plantings has thus far amply sustained the climographic prediction that we made for it, we are unable to assess the operation of other factors that might have made for a failure of the introduction. It is quite possible that the initial releases were too small;

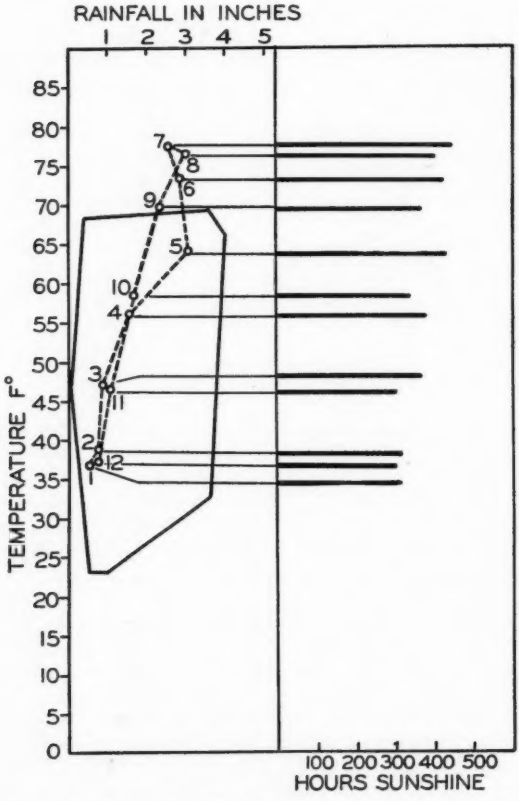

Fig. 4.—Climograph for the Amarillo, Texas region. (See Fig. 3 for explanation).

that many of the birds died of shock after release; or that the predators of the Texas panhandle took a heavy toll after the release.

Wisconsin Population Studies

CENSUSES

Seasonal inventory of game populations is essential to the understanding of population mechanics and of species ecology, so before exploring the summer ecology of the Hungarian partridge it was necessary to see how many partridges were present on the study area.

At Faville Grove spring and fall censuses of Hungarian partridges were taken. The censusing method was to drive the entire area systematically with a crew of "beaters." A bird dog was also used as a check against overlooking strays, singles, or tight-sitting birds. The census figures are shown in Table 4. The two spring counts of Hungarian partridges that were not taken are believed to have been decreases. These figures were checked and rechecked as the coveys were watched and studied during the winter.

In order to test whether the Faville Grove densities were typical of average Hun range, an area of 32,000 acres surrounding Faville Grove and comprising 189 farms was also censused during the winters of 1941 and 1942.

TABLE 4.—Faville Grove Censes.[1]

	1934–35	1935–36	1936–37	1937–38	1938–39	1939–40	1940–41	1941–42	1942–43
Fall Count	118	223	178	3142	111	175	168	120	92
Spring Count	.....	73	145	200	62	.....	108	73	56
Winter Loss									
Number	.....	150	33	114	49	.....	60	47	36
Per cent	.....	67	19	36	44	.....	36	39	39
Summer Gain									
Number	.....	.....	105	169	–89	113	.....	12	19
Per cent	.....	.....	144	117	–45	182	.....	11	26
Acres Per Bird									
(fall count)	10	10	12.5	7.5	21.6	13.7	14	20	26

1 The first year 1200 acres were censused, the second and third years 2200 acres, and in the remaining years 2400 acres were censused.

2 Hawkins states this figure was slightly high due to influx.

The census method was to interview in person each farmer to find out the size, range, and feeding location of any partridge covey on his farm. The data thus obtained were checked by personal observations and further checked by interview with the farmer's neighbors. Considerable care was exercised to prevent coveys from being duplicated or overlooked. County road-men and mail carriers also helped to locate these winter coveys. In 1941 sixty per cent of all coveys thus located were checked by McCabe. In 1942 thirty per cent were checked. The covey locations for the two years are shown in Figure 5, and the data are as follows:

	1941	1942
Total number of partridges	1208	917
Total number of coveys	109	93
Average size of winter coveys	11.1	9.2
Acres per bird	21	29
Acres per covey	230	277

These data indicate that the Faville Grove area had a typical partridge population. There was a decline in population on both areas in 1942. Despite a lower population on the large area, there was a bird per 21 and 29 acres during 1941 and 1942 respectively, while Faville Grove had a bird per 14 and 20 acres for the same years.

England has high partridge densities. Of six estates described by Maxwell (1911: 136-176) where breeding stock and best hunting bag are known, the average breeding stock is one pair per 8-10 acres; the hunting bag averages one bird per acre. The pre-shooting density was at least a bird per acre in the best years, while a bird per two acres was average.

Wisconsin had partridge densities about one-sixth those of England or Canada. The question is, why? A possible answer is suggested in the comparison of the winter loss and reproductive (summer) gain in partridges at Faville Grove with that of bob-white quail (Colinus virginianus) at Prairie du Sac, Wisconsin.

	Faville Grove Hungarian Partridges		Prairie du Sac Bob-White Quail*	
	Winter loss	Summer gain	Winter loss	Summer gain
1936	67%	.....	83%	107%
1937	19	144%	69	262
1938	36	117	76	254
1939	44	–45	30	228
1940	...	182	53	105
1941	36	.....	48	86
1942	39	11	54	188
1943	39	26	80	210
Average	40%	73%	62%	180%

* Errington (1945:14).

These percentages are believed to be significant because the species are not only closely related but have about the same reproductive potential.

Since both populations were just maintaining themselves during these years, it must follow that the winter loss and reproductive gain were in balance in both species. The winter loss for the Hungarian partridge is less than that of the quail; and the reproductive gain is likewise lower. If such were not the case, the Hungarian partridge population would by virtue of the lesser winter loss soon have a comparatively high density. Hence the reason for low partridge densities at Faville Grove in all probability lies in some defect in the repro-

ductive gain, and therefore is most apt to be found in the summer ecology. This substantiates our climographic deduction that the causative factor for low density lies in the summer period.

WINTER LOSS

Winter loss can be determined by periodic counts and its cause determined by direct evidence. At Faville Grove winter loss was caused by the following:

Egress.—The movement of partridges off the Faville Grove area has contributed to "Winter Loss" as expressed in Table 4. Such loss does not imply mortality.

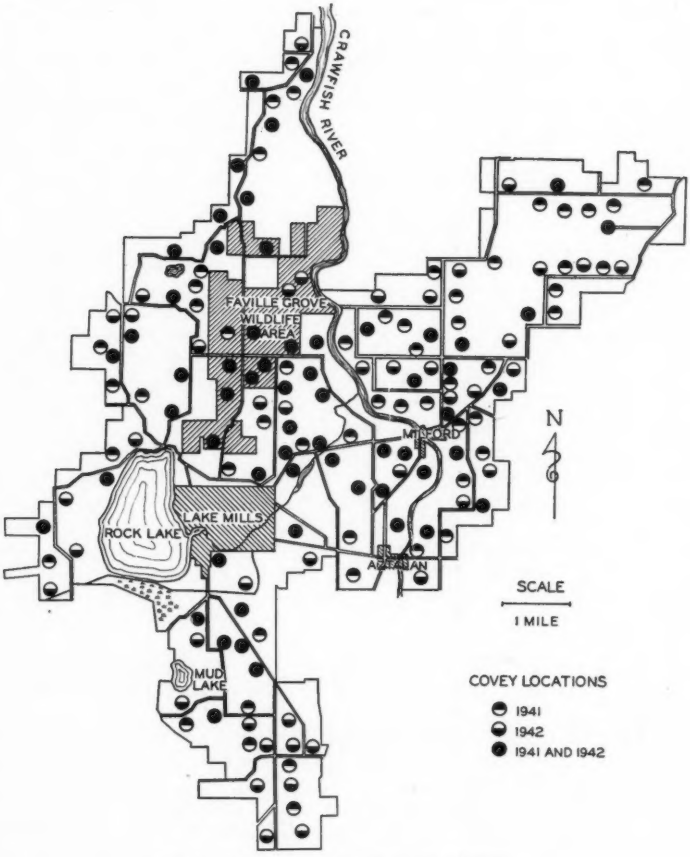

Fig. 5.—Hungarian partridge covey locations.

The departure of two whole coveys was seen in the winter of 1940-41 when the coveys moved off the area 200 yards and a quarter-mile respectively. The egress took place in December and the birds did not return. Thus the two coveys were lost to the spring census.

Ingress, or movement of birds into the area, was noted only in the winter of 1937-38, and if such influx took place during other years, it was obscured by a greater amount of egress or by mortality.

Predation.—We have no data to show week by week predation losses of birds from coveys, but we do know that horned owls and Cooper's hawks are the chief predators at Faville Grove. Cats and weasels are the principal mammal predators. During the winters of 1940-41 and 1941-42 only three known horned owl kills were found on the Faville Grove area. Of 78 horned owl pellets gathered under the only roost on the area during the 1940-41 winter, none contained Hungarian partridge remains, but only shrews, deer mice, meadow voles, rabbits and a weasel.

The horned owl (*Bubo virginianus*) population on 2500 acres at Faville Grove is shown below.

1936	1937	1938	1939	1940	1941	1942	1943	1944	Average
2	4	4	4	3	2	4	3	4	3.3

Our evidence does not indicate that predation is a major factor in winter loss at Faville Grove. Nesting predation will be discussed later.

Weather mortality.—The partridge is a hardy bird and it takes a combination of adverse weather conditions such as snow, wind, and prolonged low temperatures to bring about mortality. Two such combinations occurred during the winters of 1935-36 and 1936-37 and are recorded by Hawkins (1937: 62). The first winter brought very deep snow and continued sub-zero temperatures, and many partridges died. In January of the second winter, rain followed by freezing temperatures covered southeastern Wisconsin with a sheet of ice which remained for almost two months. Food and grit were difficult to obtain, and again many partridges perished. It was also during this winter that loss through egress took place.

Roosting habits vary somewhat with weather conditions. On mild winter nights the partridge covey may roost as a loose group, but on cold nights roost in a ring as compact as that of the bob-white. On one occasion Hawkins observed a covey of partridges going to roost in grouse fashion by plunging into a snowdrift.

Feeding habits, like roosting, conform to weather changes. When snow covers a field, they often tunnel, in one case to a depth of twelve inches, to reach the feed.

Flight accidents.—Many Hungarian partridges are killed by flying into such objects as electric wires, fences and moving automobiles. Hammond (1941: 379) in North Dakota reports that in 1940-41 the winter loss from eight coveys near five miles of highway was 60% of the total population. Of this 60% nearly half was due to automobile kills. In Wisconsin we have found that automobiles take their toll, but no dependable means of measuring numbers could be devised.

Three reasons for flight mortality as we have seen it are: First, some birds hit wires when flying downward, because the wires cannot be distinguished from the background of the earth if there is no snow. Second, Hungarian partridges go to roost late and rise early, hence are likely to fly during the semi-dark periods at dusk and dawn. Third, when a covey flies toward wires, the first birds dodge, but those behind hit the strands and are hurt or killed.

To find such birds is difficult, for when birds hit wires, the bodies may not fall on the road but drop in the ditch or adjacent field and so are easily overlooked. It is also difficult to distinguish flight kill from predation when scavenging has occurred. Flight accidents are probably more important than predation in decimating partridge numbers at Faville Grove.

CYCLE

In the United States there are no censuses or kill records long enough to yield reliable cycle data. In Wisconsin the state kill records do not show any cyclic trend. Other variables, such as hunting pressure, bag limit, and season, also affect state kill records. The censuses for Faville Grove show fluctuations, but the record is not of sufficient length to permit any conclusions.

Middleton (1934: 241) states that in England the partridge has an eight-year cycle shown by game keepers' records that extend as far back as 1850, and that the rabbit-hare cycle, though not strictly in phase, is about the same length, while the periodicity of the red grouse is six years.

The Canadian Hungarian partridge has been conforming to the grouse-rabbit cycle of approximately ten years during the last three peaks (Rowan, letter, August 1942). If there is a ten-year partridge cycle in Canada, it is longer than Middleton's eight-year English cycle. This suggests that cycle length may be determined by geographic location rather than by the species. This idea coincides with that long held by Dr. Rowan of the University of Alberta, who states (letter, December 1942), "I feel that it [answers to the Canadian-English cycle question] must lie in the environment, not in the species themselves."

A more recent letter (July 5, 1945) reaffirms the adherence of the partridge to the grouse cycle. Rowan states, "The Huns have hit the bottom again with the grouse: at least there simply weren't any across these latitudes [Central Alberta]."

More records and research are needed to confirm or deny a partridge cycle in the north central states.

Nesting Studies

In comparison with our other game birds, the mating and courtship of the partridge is most like the bob-white. Both species are monogamous and winter in coveys of mixed sex and age. Their courting is done while the birds are in these winter coveys. Territories are not taken up until after the pairs leave the covey.

The partridge begins its courting early, usually in January. In this respect it is like the prairie chickens (pinnated (*Tympanuchus cupido*) and sharp-

tailed grouse (*Pedioecetes phasianellus*)), but unlike the prairie chickens and ruffed grouse (*Bonasa umbellus*) the partridge has no showy display either in sight or in sound.

PRENESTING ACTIVITY

The prenesting activity extends from the middle of January to the middle of May, during which time several stages of prenesting behavior are recognizable. These stages overlap, but are described here as if separate and consecutive.

Precourtship chasing.—In January, fighting and "chasing" within the covey can be noted any warm or sunshiny day. Birds chase each other for short distances, the males doing the chasing (this is an assumption since there is no accurate method of distinguishing sex in the field). The birds mill about to such an extent that if any peck order exists, it is difficult to recognize. Some writers have claimed that old birds dominate both mating activities and nesting territories, but in the absence of field criteria of age, we cannot accept the claim as valid. During the chase the head and neck of the aggressor are outstretched and the wings are slightly extended along the sides of the body. The dash toward the "female" is usually a short one, in a straight line for three to five feet. Often two birds chase a single bird, but when the chased bird retires a short distance the pursuit ceases, and the birds become quiet.

Some actual combats have been observed. Two birds were seen fighting like bantams with pecking and wingbeating, and feathers were lost in the scuffle. The chase after the defeated bird was a half-running, half-flying pursuit; no second encounter occurred. Melees vary in length, form, and intensity. Farmers have also told us of such melees, which presumably are between males.

The spring combats of the partridges are not restricted to morning and evening, as is the case with the sharp-tailed and pinnated grouse, and are only occasionally localized to a particular place like the grouse. We found a few areas where several coveys often gathered to cavort in the early mornings or late afternoons of February and March. These areas were covered with droppings as thickly as are prairie chicken booming grounds. It is probable that at these communal meeting places an exchange of birds between coveys occurs which would eliminate any danger of what many sportsmen fear most—inbreeding. We do not know whether there is an exchange of individuals between coveys at any other time.

Courtship.—Later on, in mid-February, chasing gives way to courtship, in which the chasing attitude is again assumed. The male (?) dashes up to the female (?) and runs in front of her. There is a series of such dashes in a half circle in front of the hen. These dashes are accompanied by a vocal demonstration, but we could not hear the sound clearly. The fanning of the tail and wings is exaggerated over that of the precourtship chasing.

The "female" at no time pays any attention to these antics, but walks along slowly with head down, feeding here and there. At certain times the display is prolonged, and at other times the "male" stops after two or three dashes and resumes feeding.

Copulation was never observed, neither was the actual pairing off of any two birds. In captivity, however, the choosing of the mate by the female and

the pairing process were seen in detail. In 1941 the pairing took place at about the same time or a little before that of wild birds, as some penned birds were in pairs while the wild birds were still in covey. In the pen, pairs isolated themselves from the others, and any unpaired intruder, either male or female, was chased away. We believe the act of coition among both wild and penned birds takes place after the pair has separated from the covey.

With the advent of warmer weather the covey disintegrates as its pairs wander off by themselves, and by the first of March the covey has lost its identity. In bad weather the pairs often reband into coveys until it clears.

Scattering of pairs.—Newly formed pairs appear to be continually on the move. We do not know whether this movement represents a search for a nesting site or whether the movement is a search for isolation. Nevertheless it is not uncommon during the motile period to see two or even three pairs moving about in perfect harmony. This tolerance among pairs is most frequently seen just after the break-up of the covey and disappears by the end of the motile period.

During and after the scattering, pairs are often seen as much as one-half mile from any known wintering location. In England where the birds are watched closely by game keepers, this spreading movement has also been noted. Middleton (1936: 813) states that in England, "There is little doubt that a large part of winter loss is accounted for by movement of birds off the estate. Most of the movement occurs in January and February when coveys are breaking up and birds are pairing."

As the motile period comes to an end the pairs become confined to limited areas where they can be seen daily, either feeding, gravelling, or dusting. These component parts of the territory are seldom more than 200 yards apart.

NESTING

Nesting site.—In this study 435 nests were found at Faville Grove and on the big area, 427 of which can be grouped as to cover type and 403 as to the plant species immediately surrounding the nest. These groupings are shown in Tables 5 and 6.

This kind of nesting study is a sampling process. Tables 5 and 6 provoke the question: Does our method of searching for nests yield a valid sample? We can shed some light on this question by splitting off from Table 5 the data from our best area (Faville Grove) and the years of greatest effort, to see if these fractions of the mass data are consistent with each other and with the mass.

During the spring of 1937, a three- to five-man crew spent a total of 510 man hours cruising for nests. Non-hayfield cover, which was mainly roadside and fencerow, received the same attention as hayfields. Twenty-four nests were found in all cover types. In 1938 with the same method and time expenditure, 27 nests were found. In both years, 50% of the nests were found in hay.

At Faville Grove during years when only one or two individuals spent only 100 man hours searching all cover types, 50% of the nests found were again in hay. The same was true on the big area. It seems, then, that as far as cover allocation is concerned our sample is valid.

The cover-type groupings in our tables are categories of the human mind and are not necessarily the criteria used by the partridge in its choice of a nest site. Some nesting data are always gathered during and after the hatching period when vegetation is advanced beyond its status at the time of nest building. Deductions as to site preference must therefore consider the condition of vegetation at the time of nest building rather than at the time of nest finding.

TABLE 5.—Cover Types in which Hungarian Partridge Nests were Found.

	1936	1937	1938	1940	1941	1942		
Cover Type	No. %	No. %	No. %	No. %	No. %	No. %	Totals	%
Hayfield	48 (55)	37 (39)	53 (52)	28 (55)	41 (65)	19 (61)	230	(54)
Roadside	25 (29)	12 (13)	14 (14)	8 (16)	6 (10)	4 (13)	69	(16)
Fencerow*	7 (8)	13 (14)	17 (17)	9 (17)	4 (6)	1 (3)	49	(11)
Grain	3 (3)	25 (27)	7 (7)	3 (6)	10 (16)	3 (10)	49	(11)
Pasture	4 (5)	5 (5)	7 (7)	.. ..	2 (3)	3 (10)	21	(5)
Orchard	.. ..	2 (2)	2 (2)	2 (4)	.. ..	1 (3)	7	(2)
Peas	.. ..	.. ..	1 (1)	1 (2)	.. ..	.. ..	2	(1)
	87	94	101	51	63	31	427	

* Includes several nests where the actual fence was not present but a vegetative demarcation indicated a former fence line.

TABLE 6.—Plant Species Immediately Surrounding Hungarian Partridge Nests.

	1936	1937	1938	1940	1941	1942		
Plant Species	No. %	No. %	No. %	No. %	No. %	No. %	Totals	%
Alfalfa	42 (73)	25 (27)	34 (33)	25 (45)	41 (64)	18 (58)	185	(46)
June grass	1 (2)	16 (17)	29 (28)	16 (29)	9 (14)	7 (23)	78	(20)
Quack grass	4 (7)	15 (16)	12 (13)	10 (18)	2 (3)	3 (10)	46	(11)
Timothy	4 (7)	7 (7)	10 (10)	.. ..	.. ..	.. ..	21	(5)
Weeds	3 (5)	4 (4)	5 (5)	2 (3)	1 (2)	.. ..	15	(4)
Oats	1 (2)	13 (14)	4 (4)	2 (3)	6 (9)	3 (10)	29	(7)
Barley	1 (2)	11 (12)	3 (3)	1 (2)	4 (6)	.. ..	20	(5)
Canary Grass	.. ..	1 (1)	3 (3)	.. ..	1 (2)	.. ..	5	(1)
Millet	.. ..	1 (1)	.. ..	.. ..	.. ..	.. ..	1	(.2)
Wheat	.. ..	1 (1)	.. ..	.. ..	.. ..	.. ..	1	(.2)
Peas	.. ..	.. ..	1 (1)	.. ..	.. ..	.. ..	1	(.2)
Corn	1 2	.. ..	.. ..	.. ..	.. ..	.. ..	1	(.2)
	57	94	101	56	64	31	403	

The investigator must remember that his categories for classifying sites have no fixed meaning. "Hayfield" is an example of a human category which may vary from year to year. For instance, in 1936 twenty-eight nests were found at Faville Grove, but less than 12% were in hay. The obvious conclusion at that time was that the partridges preferred natural cover to hay. However, the winter of 1935-36 had been a killing winter for alfalfa, and most fields

were badly thinned. By mid-summer these alfalfa fields appeared normal, but actually they yielded abnormally light crops and our data show they were less attractive to partridges. This suggests that it is not the plant species that determines nest selection, but rather the density of the cover it offers at the time of nesting.

Since this study was made, Buss (Ms. pending publication) has also pointed out that pheasants discriminate between old and new sowings of alfalfa, the former presenting dry alfalfa stubble of the previous year, while the latter presents only the sparse stubble of the grain nurse-crop. Perhaps partridges make a similar distinction.

There are other seasonal changes that are operative during the nest building time which become obscured by midsummer. Roadsides which in July may appear to be good nesting locations were undesirable in spring because of spring burning, road grading, fence fixing, and molestation by farm dogs.

The effect of edge on the choice of a nest site has been discussed by many authors. Yeatter (1934: 27) in his Michigan study found that the Hungarian partridge had a tendency to nest close to the border of fields. We also have found this tendency of the birds to nest along borders of hayfields or in strip cover. The distances to the periphery of cover from nests that were found in this study are given in Table 7.

TABLE 7.—Distances from Nest to the Cover Periphery.

Distance to Periphery	Number of Nests						Total
	1935	1936	1937	1940	1941	1942	
0–10 feet	1	8	26	25	18	13	91
10–30 feet	2	5	12	6	12	6	43
30–60 feet	2	4	21	10	12	5	54
60–100 feet	..	4	4	3	1	4	16
over 100 feet	..	2	3	6	..	1	12
	5	23	66	50	43	29	226

This, however, is another case where human categories may not hold up as criteria for animal preferences. For example, there were in each hayfield many bare spots such as wagon tracks, lanes, gullies, and frost-killed islands all of which may have represented "edge" to the partridge but not to us. The evidence nevertheless indicates that the partridge tends to select a nest site near the actual edge (boundary) of the hayfield.

Nest construction.—How a partridge builds its nest is a matter of speculation since the act of building, as far as we know, has never been seen. Over 400 nests were examined during this study, and from the observations made the following deductions are drawn.

A scrape is always made, regardless of whether it is a first or second attempt at nesting. This depression is usually about two and one-half inches deep and from six to eight inches across. Into this scrape a nest is built. The amount and kind of nest material depend on the cover type in which it is built: nests in grass contain more material than those in hayfields. One com-

mon characteristic of nests, except those in grain, is that the lining is made of broken stems and leaves of herbaceous plants of the last year's growth. Composing the rim of the nest are longer strands of dead vegetation, and plucked green materials of the present year's growth. The latter are sometimes added after eggs have been laid.

In grain fields we found, as Yeatter (1934: 27) did, that the scrape is poorly lined with pieces of green field weeds and a few grain leaves.

One use of the broken material in the nest is to cover the eggs when the hen leaves. This covering-up is characteristic of nests not yet being incubated. After incubation starts this practice is abandoned.

The thoroughness with which the hen covers her eggs is surprising. On one occasion a female flushed from a fencerow, but on first examination of the spot we could find no nest; only after a careful search on hands and knees were the eggs discovered. All of the nest except an area about an inch in diameter was covered with a mat of broken plant debris. When the covering was removed, the nest, in which there were four eggs, measured six and a half inches across.

Nest covering affords concealment, and perhaps insulation from chilling weather or excessive drying from warm winds. Earthworms and slugs are sometimes found under the lining of the nest, showing that the scrape is not dry. The damp ground underneath the nest may help keep the eggs humid during incubation.

Rain caused the break-up of five nests out of 435. No attempt was made to classify the drainage of all nest sites, since such a classification is at best only

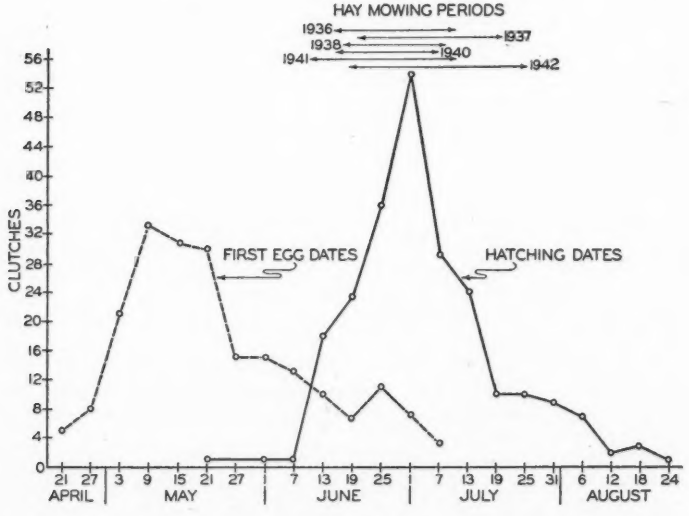

Fig. 6.—Frequency distribution of first-egg dates and hatching dates, 1936-42; relation of hatching to hay-mowing periods.

relative. It appears that the partridge does not select its nest with regard to proper drainage.

The first egg is apparently laid shortly after the nest is constructed.

Egg laying.—The partridge may start laying as early as the middle of April, but most nests receive their first egg about May 15. The date of first egg can be computed when clutch size, rate of egg laying, and incubation period are known, all of which will be discussed later. Fig. 6 shows the spread of first-egg dates for 189 nests. We wanted to know the height of nesting cover during egg laying, but this could seldom be measured directly because most nests are not found until later. Two sample plots one yard square were staked out in each of three cover types and were measured twice weekly during the egg laying period. (Fig. 7.). At the date of first egg (May 15) no cover type had made less than twelve inches of new growth.

We found the rate of egg laying for wild partridges to be about 1.1 days per egg. The eggs are laid at the same rate as those of the quail (Stoddard 1931: 26). Other writers give the following rates for Hungarian partridges:

Yeatter (letter)	–1.1 days, agrees with this study
Hunt (1939:4)	–1.3 days (63 eggs in 83 days, penned ♀)
Sprake (1930-61)	–1.4 days ("about 5 eggs a week")
Portal and Collinge (1932:51)	–1.4 days (quoting Ogilvie)

The rate of egg laying in the wild may be obscured by two hens laying in the same nest, or by predators removing eggs without disturbing the nest or the incubating hen. Sprake (1930: 61) says that the number of eggs laid per unit of time is apt to vary with the weather or with the individual bird.

Most popular and semi-popular articles on the partridge state that the bird lays large clutches, and records of 22 to 26 eggs per nest are cited. We have

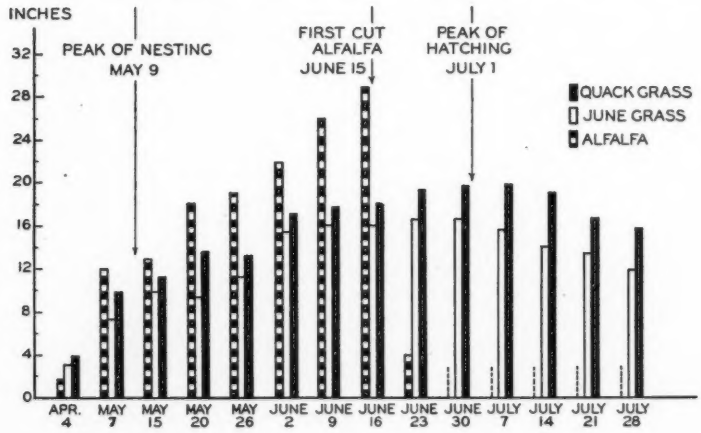

Fig. 7.—Growth rates of Hungarian partridge nesting cover (1941)

seen a number of 22-egg nests, but when all clutches are averaged the figure falls to about 17 eggs per clutch. A compilation on clutch size in different regions is presented in Table 8., from which it seems that the clutch size in

TABLE 8.—Clutch Size of Hungarian Partridges.

Writer	Place	No. Clutches	Average Clutch		Nesting			
					1st Attempt		2nd Attempt	
Middleton[1]	England	4090	14.6	14.3	?		9.9	9.4
Sprake	England	?	14.0		?		9.0	
Yeatter[2]	Michigan	44	15.7		17.2	17.2	9.3	9.9
This paper	Wisconsin	392	16.5	16.4	17.2		10.5	
Yocum	Washington	44	17.1		?		?	

1 Middleton's data cover 36 English estates from 1933 to 1934 and one estate from 1911 to 1933.

2 Yeatter's 1930-33 data are divided into clutch size per month from June through August. The first two months are first nestings; the last are regarded as second attempts; and the three months' data are used to get the average clutch size.

England is smaller than in the United States, but that within the two countries clutch sizes remain about the same in various regions. The clutch size of the Hungarian partridge in Canada would be very enlightening, but as yet there are no published data.

Hungarian partridges in captivity often lay as many as sixty eggs (Hunt 1939: 5) if the eggs are removed periodically, and have been known to lay 100 (Bracher 1931: 34) during a nesting season. The number of eggs required in a nest to keep the hen laying and to delay incubation is uncertain, but our penned birds have incubated two or three eggs when the impulse became strong enough. In the wild the smallest incubated clutch we found was five eggs. The process that causes the hen to stop laying and begin incubating is known to be physiological, but how it varies with the season, endocrine function, and age of birds, is not known.

The sizes of eggs vary, which fact became apparent after the length and width of 1900 eggs had been measured with a caliper. Bent (1932: 4) presents Hungarian partridge egg measurements by Jourdain in England. The two sets of measurements are compared as follows:

	No. of Eggs	Largest		Smallest		Average	
		Length	Width	Length	Width	Length	Width
This Study	1900	39mm	28mm	26mm	23mm	35.4mm	27.1mm
Jourdain	100	38.9	28.4	33.8	26.3	36.8	27.4

The greatest difference in length within a clutch was 4mm (38mm-34mm) and in width 2mm (27mm-25mm). The size extremes found in this study are shown in Fig. 8.

Runt eggs apparently occur less frequently in the nests of the partridge than in the bob-white nests as described by Stoddard (1931: 69). In five years we have but one Wisconsin record of a runt egg. William H. Elder on May 14, 1942 (letter), found a Hungarian partridge nest at Barrington, Illinois, with two miniature eggs in it.

The only other abnormality in egg structure was a clutch with eggs having several wrinkles or creases in the shell at the pointed end. The eggs were otherwise normal in that they were fertile and produced a brood.

Incubation.—We found at Faville Grove, and it has been recorded by many writers, that birds not incubating, or in the early stages of incubating, will desert the nest if disturbed or molested. The tendency to desert is gradually lost as incubation progresses; however, this rule has many exceptions since the tendency differs with each female.

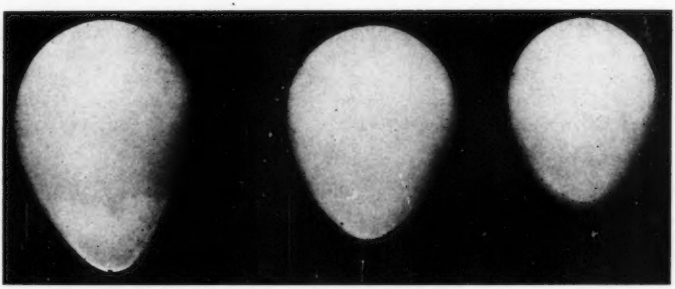

Fig. 8.—Size variations in Hungarian partridge eggs. Left, 39mm. × 28mm.; center, 34mm. × 26mm.; right, 26mm. × 23mm. The average is 37mm. × 27mm.

Birds that have been incubating ten days or more can usually be approached closely enough to distinguish the cross-barring on the median wing coverts. During the last week of incubation most females will not leave the nest until touched lightly with the hand. In most cases the female runs instead of flying from the nest to nearby cover. None was known to defecate when forced from the nest.

The female spends from two to three hours away from the nest each day. The rest periods are usually early in the morning and late afternoon, when the birds feed and dust. While sojourning from nest duty, incubating hens are always accompanied by their mates, who are seldom more than fifty yards away from the nest.

Eggs being incubated have a characteristic formation in most nests. The eggs are arranged in orderly fashion with the blunt end up (in contact with the female's body). The nest cup has the appearance of a cobblestone pavement. The eggs in an unincubated nest are in no set position; one or more eggs may be on top of the rest. This has often led farmers to say of a nest that it had eggs in it "two-deep." Low (1941: 509) writing on the nesting of the ruddy duck in Iowa has observed this same egg arrangement. He says,

"Data from the present study indicate that eggs were often piled in a nest in several layers before incubation began. However, once incubation started, the eggs were placed on one level."

The cobblestone arrangement of the eggs in the nest with tips down we first thought to be an exact criterion of whether incubation had begun, but on careful analysis we found that this position was characteristic only of large clutches during incubation. This arrangement seems to be necessary in order for the bird to cover the clutch and to incubate properly. Small clutches (8 to 10 eggs) showed no consistent tendency to adhere to the cobblestone position Eggs of small clutches are also apt to roll into new positions when the hen leaves the nest.

During the summers of 1941 and 1942 six clutches of incubating eggs were marked and then examined periodically to check on the process of egg turning. The method was to mark and number a set of dummy partridge eggs, substitute this set for eggs that were being incubated by a wild partridge, and make periodic visits to the nest, noting any changes in position and rotation on the axis for each egg. We were able to conclude from these observations (1) not all eggs are turned at each turning; (2) an egg may be turned any per cent of a total turn; (3) an egg is usually not moved out of the original quarter of the nest. How the eggs were turned we do not know, as breast feathers, nest edge and low-growing vegetation obstructed our vision from a distance as close as fifteen feet.

A dummy set of eggs was used in these experiments in order to save the viable clutch in case the incubating bird deserted. Four of the six nests were deserted presumably because of disturbance when the eggs were examined.

The length of the incubation period as given by various writers differs by as much as four days (between clutches), but the more recent studies show the actual variation to be not more than 1.5 days. Bellrose and Hawkins (unpublished) have some information that weather conditions influence the incubation period in the wood duck. Writers have given the following incubation periods for the partridge:

Thienemann, 1845*	21 days	Germany
Yarrell, 1871*	21 days	England
Saunders, 1889*	21 days	England
Tegetmeier, 1898	21 days	England
Saunders and Clarke, 1927	21–23 days	England
Sprake, 1930	23–24 days	England
Heinroth, 1928	23½ days	Germany
Kirkman and Jourdain, 1938	23–25 days	England
Pollard, 1930	24 days	England
Yeatter, 1934	24 days	United States
Green and Hendrickson, 1938	24 days	United States
Wright, 1885*	24–25 days	England
Jourdain (quoted by Bent, 1932)	25 days	England
Evans, 1891	25 days	England
Portal and Collinge, 1932	24–26 days	England

* Quoted by Evans, 1891.

Several well known writers in the above list give 21 instead of 25 days as the incubation period. The discrepancy may have come about by translating into days the round figure of three weeks as the incubation period. Evans

(1891: 89) says, "It seems strange that the period of incubation in the case of the Common Partridge should have been so persistently stated by authors to be 21 days instead of about 24 days."

In these studies we watched for the first "bulge" of pipping in our bantam-incubated clutches and isolated these clutches to find out the length of time between the first and last chick to come out of the shell. While this period was usually fifteen hours, there were instances where 24 hours elapsed between the first pipping and the last emerging chick. Hart (1943: 5) gives this interval as 28 hours. It appears, therefore, that prolongation frequently occurs and that 1.5 days disparity between various accounts is not surprising. This may also be a matter of definition.

Our findings indicate that the incubation period, which is the interval between the start of incubation and the time when the last chick is out of its shell, is 25 days. Although the first egg may hatch during the afternoon or evening of the twenty-fourth day, the process is not complete until the twenty-fifth day. In short, the incubation period is 24½ or 25 days (since most clutches require 25 days to hatch completely). A 25-day incubation period is therefore used in all calculations involving this interval.

Authorities agree that the hen does all the incubating, and that is also our conclusion. However, the following incident is presented as a possible exception.

On August 5, 1941, a bird behaving oddly was seen on a gravel road two miles from Faville Grove. The bird was alone and appeared to be uneasy; it made several flights but refused to leave the vicinity. On examining the spot we found a nest and a mutilated partridge 25 feet from where the bird was first seen. The remains of the dead partridge showed typical signs of cat predation, and the soft and pliable feet of the bird indicated that it had been recently killed. The nest contained 13 partridge eggs with live 17-day embryos, and two pheasant eggs. The partridge eggs were subsequently hatched and the chicks used for study. The incident was strange because the dead bird was definitely a male by the wing plumage, although the gonads were not available. Whether the male had been incubating, or whether it had attempted to fight off the attacker of the female and was so killed, is a matter for conjecture, but ordinarily a cat kills the incubating female and allows little time for the male to come to the aid of its mate.

Another peculiar incident was noted among our penned birds. On July 16, 1942 a male was seen sitting close at the side of an incubating female. The male was unusually wild ordinarily, but on this day, while watched for some time at close range, he refused to leave the female. Such attention by the cock was not seen again and is not offered as proof that males help with incubation. More recently Hart (1943:4) has observed a pair of partridges on a single nest and was fortunate enough to photograph them. He found that this occurred only after the eggs began to pip.

Stoddard (1931: 31) records a male and female bob-white that incubated a clutch side by side.

Weight loss of the egg during incubation.—As the embryo within the shell of an incubating egg increases in weight, the gross weight of the egg lessens. This weight loss is caused by the evaporation of moisture escaping through the pores of the egg shell. To measure this loss for Hungarian partridge eggs,

all eggs incubated by our bantams during the summer of 1942, both wild and pen-laid, were weighed daily. A total of 1143 measurements was made, but because of the infertility of many of the pen-laid eggs, only 574 measurements were valid. The results of these weighings are shown in the weight loss curve of Figure 9.

The air cell of the egg increases in size during the incubation period until it reaches about one-fourth of the egg volume just before hatching.

Hatching.—After 25 days of incubation, with some slight variation, the eggs of the partridge hatch. The sight of the young birds coming out of the shell has been described many times and is a sight worth recording. The newly hatched birds require from one to two hours to emerge from the shell and get completely dry.

The agility with which the newly-hatched young are able to escape danger is surprising. On July 18, 1940, a nest was discovered in a night pasture grown mostly to sweet clover. The nest was in a circle of clover three feet across and two feet high which had been only partly eaten by cattle, while the area around the circle was grazed within an inch of the ground. On July 20 at three in the afternoon the nest site was carefully approached, but the female was not on the nest. When the observer had approached within two feet, he was set back sharply as both male and female birds rushed from the small patch of cover toward him. Both birds circled the feet of the intruder, each dragging one wing in a desperate feigning effort. After the observer had retreated about 25 feet both birds became erect, and the female, who was easily distinguished by her

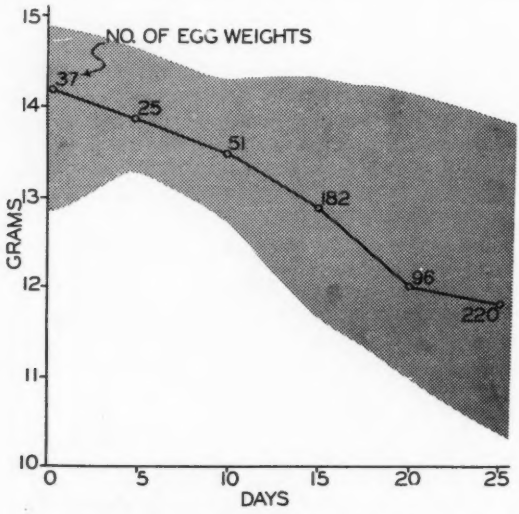

Fig. 9.—Average and range of weight loss for Hungarian partridge eggs during incubation.

more mottled coloring on the wings, ran toward the nest uttering a series of throaty sounds, bur-r-r-ruk! bur-r-r-ruk! The male ran into a patch of field beans 40 feet away. As the hen approached the nest, the seven chicks came running from the nest cover and followed her into the bean field at the exact spot where the male had disappeared. The young birds took two minutes to travel the 40 feet. Examination of the nest revealed that one egg had been eaten by a predator and two embryos had died in the shell. The egg membranes were dry but adhered strongly to the eggshell, indicating that the birds had been hatched just a short time before.

The preceding account illustrates several points pertinent to Hungarian partridge hatching: that the male is on hand when the young are hatched, that the young are very agile and leave the nest soon after hatching, and that there is a rest period before the family leaves the nest site. This ability of the young chicks to leave the nest at a very early age was noted as early as 1768: White in his "Natural History of Selborne" (1889: 55) says of the stone curlew, "The young run immediately from the egg like partridges."

After the young leave the nest there are left behind the decapped empty shells, any eggs in which embryos died during incubation or which were too weak to pip the shell completely, and infertile eggs. From hatched nests we are then able to determine the hatchability of the clutch. It was found that 104 hatched nests contained 1838 eggs, 84.5% of which were hatched. The yearly hatchability varied.

1936	1937	1938	1940	1941	1942	Average
93%	85%	74%	91%	88%	76%	84.5%

Middleton (1935: 802-803) found that from 27 English estates over different years from 1911 through 1934 the hatchability for 4090 nests was 93 per cent, which is 9 per cent above our average. In no one year did the average fall below 90 per cent, and the poorest year on any one estate was 86 per cent. All eggs were laid and hatched in the wild. Middleton does not state what per cent of the unhatchable eggs were infertile. We kept fertility records on 2,000 eggs of wild partridges, and the figures are given in Table 9. In an old nest it was difficult to determine whether an egg or an entire clutch was infertile, unincubated, or dead after a short period of incubation. Doubtful material was not used in Table 9.

TABLE 9.—Egg and Fertility Data.

	1936	1937	1938	1940	1941	1942	Totals
No. of eggs studied	122	420	677	403	243	195	2060
No. of infertile eggs	8	63	120	25	22	44	282
Per cent of infertile eggs	6.5	15.0	17.6	6.2	9.0	22.6	13.7

Nesting results.—We have concluded from our population studies that the place to look for causes of low density is in the summer ecology. The success or failure of nesting attempts is therefore important. The causes of nest failure

TABLE 10.—Causes of Nesting Failure.

Cause	1936			1937			1938			1940			1941			1942			Total		
	No.	% of Fail.	% of Tot.	No.	% of Fail.	% of Tot.	No.	% of Fail.	% of Tot.	No.	% of Fail.	% of Tot.	No.	% of Fail.	% of Tot.	No.	% of Fail.	% of Tot.	No.	% of Fail.	% of Tot.
Mowing	22	76	(28)	57	76	(53)	50	64	(50)	39	92	(71)	44	90	(69)	17	74	(55)	229	77	(53)
Predation	6	21	(7)	7	9	(7)	14	18	(14)	..	..	..	3	6	(4)	1	4	(3)	31	10	(7)
Cutting weeds by hand	..	..	..	7	9	(7)	6	8	(6)	1	2	(2)	..	..	..	4	18	(13)	18	6	(4)
Grazing	1	3	(1)	2	3	(2)	4	5	(4)	1	2	(2)	1	2	(2)	..	..	..	9	3	(2)
Plowing	..	..	..	2	3	(2)	1	1	(1)	..	..	..	1	2	(2)	..	..	..	4	1	(.9)
Harvesting	..	..	..	..	..	..	..	..	..	1	2	(2)	..	..	..	..	..	..	1	.3	(.2)
Rain	..	..	..	..	..	..	3	4	(3)	1	2	(2)	..	..	..	1	4	(3)	5	2	(1)
TOTAL	29	..	(36)	75		(71)	78		(78)	43		(79)	49		(77)	23		(74)	297		(68)
No. of successful nests	49	..	(64)	32		(29)	22		(22)	12		(21)	15		(23)	8		(26)	138		(32)
TOTAL	78			107			100			55			64			31			435		
Females killed	6		(7.6)	9		(8.4)	13		(13.0)	6		(10.9)	8		(12.5)	3		(9.7)	45		(10.3)

as encountered in this study are shown in Table 10. The various causes of failure correspond with an associated cover type, e.g. the greatest number of nests were found in hayfields, and mowing of hay caused the most nesting failures. Predation, the second largest cause of failure, occurred mostly along roadsides and fencerows.

Of 435 nests found: 68% failed; mowing was responsible for 53% of the failure; 20% of the incubating females of the unsuccessful nests were killed either by the mower or by predators; ringnecked pheasants parasitized 1% of all nests studied. The most successful year for the partridge was in 1936 when only 37% failed; 1942 was the poorest year with 74% failure.

Alfalfa hay fields, abundant throughout the southern section of the state, are the preferred nesting areas of the Hungarian partridge in Wisconsin. The time at which the hay is cut is therefore important to the success of nesting, since cutting destroys nests, kills incubating females, kills broods (especially those that cannot yet fly), and removes cover for possible second nesting attempts. The hay mowing periods from 1936 through 1942 were tallied by direct observation and personal interview. These periods, when plotted in relation to the partridge hatching dates (Fig. 6), show that the peak of hatching for the past six years has always been during the mowing period. The quantitative results of this coincidence have been shown in Table 10.

This coincidence between the phenology of the partridge and that of alfalfa is undoubtedly one of the main causes for low density in the north-central states. It is worth noting that alfalfa is virtually absent from the partridge range in the Canadian wheat belt, while in the states of Washington and Wisconsin alfalfa comprises about 10% of the crop land per farm. Washington has comparatively high partridge densities while Wisconsin has low densities; both ranges have about the same per cent of hayfield mortality. It follows that partridge range of Washington has qualities that can maintain partridge densities despite heavy hayfield mortality, while Wisconsin does not.

We recognize that nesting failure does not necessarily mean that the pair will not eventually raise a brood. Partridges renest successfully. The compensatory value of renesting can only be computed with mass data on nestings and broods (Errington and Hamerstrom, 1937: 12). We lack sufficient reliable brood data to determine such a value for the partridge.

TABLE 11.—Comparison of Nesting Failure in Various Studies of Game Birds.

Species	Authority	Year Pub.	Per Cent Failure	Total Nests
Lophortyx c. californica				
Valley quail	Glading (Calif.)	1937	82%	96
Phasianus colchicus				
Pheasant	Hamerstrom (Iowa)	1936	77	445
Perdix perdix				
Hungarian partridge	Yeatter (Mich.)	1934	68	143
Hungarian partridge	Yocom (Wash.)	1943	68	68
Hungarian partridge	This study (Wisc.)	1946	68	435
Colinus virginianus				
Bobwhite quail	Stoddard (Georgia)	1931	64	602

TABLE 11.—Comparison of Nesting Failure in Various Studies of Game Birds.—Con.

Species	Authority	Year Pub.	Per Cent Failure	Total Nests
Phasianus colchicus Pheasant	Errington and Hamerstrom (Iowa)	1937	62%	251
Lophortyx g. gambelii Gambel quail	Gorsuch (Ariz.)	1934	61	44
Phasianus colchicus Pheasant	Buss (Wisc.)	1941	60	124
Lophortyx c. brunnescens California quail	Sumner (Calif.)	1935	60	?
Bonasa umbellus Ruffed grouse	Bump (N. Y.)	1932	57	(100 eggs)
Colinus virginianus Bobwhite quail	Errington (Iowa)	1933	51	69
Tympanuchus cupido Prairie chicken	Yeatter (Ill.)	1943	51	39
Prairie chicken	Gross (Wisc.)	1930	50	40
T. cupido and *Pediocetes phasianellus* Prairie chicken and sharptail grouse	Hamerstrom (Wisc.)	1939	50	100
Aythya americana Redhead	Low (Iowa)	1940	45	42
Branta canadensis Canada goose	Dow (California)	1943	44	418
Anas discors Blue-winged teal	Bennett (Iowa)	1938	40	223
Centrocercus urophasianus Sage grouse	Rasmussen and Griner (Utah)	1938	40	161
Philohela minor Woodcock	Mendall and Aldous (Maine)	1943	38	136
Zenaida asiatica White-winged dove	Arnold (Ariz.)	1943	36	128
Bartramia longicauda Upland plover	Buss and Hawkins (Wisc.)	1939	34	47
Erismatura jamaicensis Ruddy duck	Low (Iowa)	1941	27	71
Branta canadensis Canada goose	Williams and Marshall (Utah)	1937	19	(410 eggs)

To compare nesting failure as found in this study with other nesting studies on this and other game birds, Table 11 is presented. The consistency of the per cent of failure in Hungarian partridge is peculiar and its meaning is not understood.

Nesting failure sometimes means loss of both the incubating bird and the eggs. During this study mowing and predation caused 260 nest failures. In 45 (17%) of these failures, the incubating bird was also killed. No sight is so depressing to one working with game birds as a mowed-over nest containing a clutch of broken eggs and the legs of the unfortunate hen. A flushing bar

might prevent such accidents, but not one of 160 farmers interviewed used a flushing device, primarily because of anticipated difficulty in its construction and use. A flushing bar is useless on a fast moving mower and would defeat the advantage of tractor mowing; namely, speed.

Pheasants laid eggs in 6 of our 435 nests, or 1%. Such parasitism by pheasants often led to nest failure. One nest was successful for a partridge whose clutch was partly incubated before the pheasant eggs were deposited, and hence hatched first. Another was taken over by a pheasant who laid eight eggs into a clutch of eight partridge eggs, and then began to incubate. A day after the pheasant chicks hatched, the pipped partridge eggs were found with all embryos alive, deserted because the pheasant incubation period is two days shorter than the partridge's. The other four nests were either deserted or broken up. In Iowa, Errington and Hamerstrom (1938: 72) found seven parasitized partridge nests in a total of 26 (27%). In no case do we have and record of a partridge parasitizing a pheasant or quail nest.

While our method of nest finding (as discussed under *Nesting*) was apparently valid as to the selection of cover types, it failed to account for a large percentage of the possible nesting pairs. In the years of most intensive search and largest total of nests found, we were able to account for only a quarter of the spring population:

Year	Potential number of pairs present in March	Nests found May-July
1936	111	28
1937	89	24

A subsequent search for overlooked nests and for broods indicated that few if any nests had been missed and that 25% of the spring population was all that nested on the area. What, then, happened to the remainder of spring survivors?

There are four possible answers:

One, that birds moved off the area between the spring census and the nesting period. This seems unlikely because the surrounding areas showed no greater breeding density than Faville Grove.

Two, that there were many non-breeders. This is likely, as there were wandering pairs often seen during the nesting and brood period, but these were at the time believed to be unsuccessful nesters. Whether these birds were of one sex, indicating an unbalanced sex ratio, is not known.

Three, that there are nests that failed so early as to leave no vestiges and so escaped detection. While this is probable, it is doubtful that in six years we could have missed it completely.

Four, that there is heavy mortality between the spring census and the nesting period. This likewise is doubted in view of our constant vigilance in the field.

In short, we have no data to show what happened to the 75% of the spring population that could not be accounted for as breeding pairs. Extensive trapping, plus banding with metal and colored bands, taking sex and age

ratios of banded birds, and checking seasonal movements with field glasses might lead to a possible answer.

Dummy nests.—Nest predators are of two kinds, one that kills the incubating bird and the other that eats the eggs. The cat is the only animal we found to prey on incubating birds. Field observations indicated that ground squirrels, skunks and crows are egg eaters. Each of the egg-eating animals leaves its particular "sign" where the predation occurred; hence correct reading of such evidence can determine the predator involved. The following experiment was conducted, first, to determine what animals eat eggs, and second, to help identify "sign" of the various egg predators.

Eggs from deserted nests were placed in dummy nests which were constructed to look as much like real nests as possible. These were made in various locations, but all within easy reach of ground squirrels, skunks and crows. Two hundred partridge, pheasant, and bob-white quail eggs, which had been salvaged from mowed-over or deserted nests, were set out in 21 nests. The results follow:

1. The Franklin ground squirrel (*Citellus franklinii*) ate the eggs of all three species. The egg is opened at the blunt end, and the egg membrane is usually eaten. Tooth marks were found around the opening, where small pieces of shell are bitten away. The edges of the opening are not shattered. Rotten eggs are often taken, and sometimes appear to be preferred to fresh ones. Removing eggs and rolling them a considerable distance from the nest is a habit of the ground squirrel, the entire procedure being completed without breaking the egg. Sowls (1941) gives a detailed description of the predatory habits of this mammal.

2. The 13-lined ground squirrel (*Citellus tridecemlineatus*) predation is similar in most respects to that of the Franklin ground squirrel, especially in the egg-rolling habit. The striped ground squirrel was found to prefer quail eggs, to take Hun eggs only occasionally and pheasant eggs not at all. Pheasant eggs are too large for the small gopher to handle.

3. The skunk (*Mephitis mephitis*) is the easiest culprit to identify, for it is the most slovenly in its manner of eating eggs. The opening in the egg may be made either at the end or on the side. The shell surrounding the hole is smashed in so that at least half the egg is broken. The shell is invariably messy and yolk-stained. Sometimes eggs are rolled from the nest and at other times the egg remains are found in the nest. No eggs are known to be too large or too small for the skunk, and it will sometimes eat rotten eggs.

4. The crow (*Corvus brachyrhynchos*) leaves its telltale evidence as it pierces the egg with its bill. The hole is about the size of a dime and is clear-cut. There is usually a smaller hole on the opposite side, made when the bill pierces through both walls of the shell. The egg membrane is seldom eaten, and there is no yolk-staining. The crow eats eggs by "sucking" the contents out of the shell. This eliminates spillage and messy predation residue. Egg sucking by crows was recorded by Kalmbach (1918: 30) and the detailed process explained by Brooks (1939: 66).

5. Eggs were refused by woodchucks and fox squirrels, although squirrels elsewhere are known to be major egg predators in smaller species. Insects often attack broken eggs after predation and leave markings on the shell. These

markings are similar to tooth and claw scratchings and should not be confused with predator sign. Tracks and hair left at the scene of the predation sometimes help to identify the predator. In the case of the crow it is well to examine both the nest and the area around a nearby loafing perch for egg remains.

Analysis of Nesting

In any analysis of the nesting season, we need a reckoning point in time, so that the events of the nesting cycle can all be related to one fixed datum point. In this study the date of first egg is so used.

Computing Nest Phenology

When any event of known date in the nesting cycle is separated from the date of first egg by intervals of known length, the date of first egg can be computed. In order to do this we must know the clutch size, the rate of egg laying, the interval between the end of laying and incubation, the length of incubation, and in deserted nests the age of the embryo (the term "desertion" will be here used synonymously with "nest break-up"). These items are obtained as follows.

The clutch size of a broken-up nest is easily determined by counting the eggs or shells, but the area around the nest should be thoroughly searched for eggs broken or rolled away by ground squirrels.

We found the rate of egg laying for wild Huns to be about 1.1 days per egg (see earlier discussion).

The interval between the end of laying and the beginning of incubation we found to be about one day.

The length of incubation, as previously discussed, is twenty-five days.

The age of the embryo was at first estimated from its general appearance. These age "estimates" made during the first two years of the study were subject to an error of $\pm$ three days. Accordingly we devised more accurate criteria which are later described. These came too late to be used in this study, but are available for future work.

Knowing the values for these five items, the date of the first egg is then computed as follows: the clutch size is multiplied by 1.1 to get the egg laying period, and one day is added for the rest interval between the end of laying and incubation. The age of the embryo in days is then added, and the total days subtracted or dated back from the date of nest desertion. That is to say, subtract from the date of nest break-up the sum of three periods:

Days of egg laying (clutch size × 1.1)	A days
Interval between laying and incubation	1 day
Days of incubation (age of embryo)	B days
Days since first egg	= A+B+1 days

Just as the date of first egg is computed by dating back from the time of desertion, so the hatching date may be determined by adding to the desertion date the difference between the age of the embryo and 25 days (incubation period).

Hatching date = Desertion date + (25 days − age of embryo) The accumulated data on the date of first egg and hatching date are shown in Fig. 6.

AGING EMBRYOS

The age of an embryo is determined by a particular stage in its development, hence the first step in the aging process is to find out what changes take place from day to day in growing embryos.

To ascertain the growth rate of partridge embryos, incubating eggs were opened and examined daily. During the nesting seasons of 1938, 1940, 1941 and 1942, 450 eggs were gathered from mowed-over and deserted nests. To keep track of the eggs after they were collected, each was weighed, measured and given a number. Unless these numbers were put on with drawing ink, they were rubbed off by the incubating bantam hen.

Elimination of errors.—In 1938 the eggs were divided into two lots for hatching, one placed under bantams and the other in an incubator. No perceptible difference was shown between the two methods of incubation. In 1940, 1941 and 1942 only bantam incubation was used. Eggs were placed under a bantam as soon as possible after they had been found, which was seldom more than six hours after the nest was broken up. Overexposure to the heat of the sun or chilling during the interim may arrest normal embryo development and introduce an error. However, if salvaged eggs are still viable, there is reasonable assurance that such error is not great.

General procedure.—The procedure in examining embryos was to remove the egg, weigh it, then decap[4] it, noting size, shape, position and anatomical characteristics of the embryo. A written description and sketches were then made of all external characters. The yolk sac and embryo were separated and their wet weights taken to the nearest tenth of a gram. The embryo was then immersed in a fixative for several hours, after which it was labeled and placed in a vial with alcohol or formalin to be used in sexing and histological studies. All characters described in the key to follow are those that can be seen with the naked eye. To check the accuracy and to make detailed drawings a binocular dissecting microscope was used.

Techniques.—The examination of a single embryo has taken as long as three hours. Time-saving devices over and above standard equipment were applied in the following ways. To hold eggs while they were being worked with, a wooden block was used in which holes were bored large enough so that the eggs, apex down, were held securely, thus leaving both hands free for dissection or drawing. This block eliminates the mixing up of eggs and the chance of an egg rolling off the table. Adhesive tape is an excellent repairing material in case of a crack or slight breakage.

In cutting free the cap of the egg, a small sturdy pair of scissors is employed in short rapid snips without cracking the bulk of the egg shell. Two pairs of pointed tweezers will help to remove any obstruction (usually shell membrane) which prevents clear view of the embryo. To weigh specimens intact it is best

4 To decap an egg is to remove the crown of the egg at the blunt end, taking off about as much as is removed by the chick when hatching.

that they be placed on a piece of wax paper, which prevents the absorption of body fluids and the adhesion of the delicate membranes or feathers to the weighing pan. For microscopic examination a gooseneck study lamp should be used for best lighting; however, care must be taken so that the heat of the lamp does not dry the specimen. In order to prevent this drying, the embryo should be placed in a chemist's watch crystal and moistened occasionally with water from a Florence flask chemical washer. This washer is invaluable in many other ways. A blunt-pointed dissection needle bent like a shepherd's crook is employed in moving and examining the appendages and feathers.

An embryo should never be lifted by any of its appendages, its head, or body alone; the entire embryo should be moved en masse. If the specimen is to be used for detailed morphological studies, the desired parts should be fixed (body cavity opened in large birds) in Bouin's fixative.

Embryo growth and development.—The most difficult period for determining the age of an embryo is between the first and sixth day. During the first three days the embryo develops from a tiny streak on the yolk sac to a small, curved white form between 7 and 9mm in length, within which there is a visible pulsating organ. The embryo at this stage is too light to be weighed on a field scale. Little change is noted on the fourth day, but by the seventh day the eyes and the limb buds are clearly defined, and the embryo is large enough to be weighed (0.2 gm). On the eighth day the embryo takes on its bird-like shape with head, neck, body and tail regions differentiated. Development continues until a weight of 0.5 gm is reached by the tenth day and the egg tooth or pipping tooth is in evidence on the rapidly developing bill.

The presence or absence of down on an embryo is one of the most important age criteria, since it marks the halfway point of incubation. Small bumps like goose-pimples, which are forerunners of the down feathers, appear along the back on the eleventh day and elongate and darken into feathers on the twelfth and thirteenth days. The "goose-pimples" appear on the ventral surface on the fourteenth day and by the fifteenth day are elongated into down.

On the sixteenth day dark feathers encircle the eye, but other head feathers are scant until the eighteenth day, after which their growth is rapid, and on the twenty-first day the head is completely feathered.

The formation and growth of the appendages also occur on particular days in the embryonic development. On the sixth day the limb buds are noticeable. The upper mandible protrudes from the head region on the eighth day but the lower mandible is not completed until the tenth day. Toenails and the beginning of scales on the legs appear on the twelfth day, and by the twenty-second day have become horny and darker in color, along with the bill. The rate of hardening of the toenails and bill can be traced daily because of the marked color difference in the hardened and non-hardened portions.

On the eleventh day it was noted that the combined leg and foot had grown to 6mm in length, and subsequent measurements of the tarsus and middle toe with claw were taken during the growth period. The measurement was taken from the middle point of the joint between the tibia and metatarsus on the posterior side of the leg and underside of the foot to the tip of the claw on the middle toe. Baldwin *et al.* (1931: 107) describe a similar measurement, which differs from ours in that it is diagonal from posterior side of

tarsus to anterior (dorsal) tip of the claw of the middle toe. Our method of measuring was also used on live chicks and adult birds, since it was obtained quickly and accurately in the field. The combined posterior length of the tarsus and middle toe with claw will be called the "leg and foot" measurement. This measurement ranged from 6mm on the eleventh day to 32mm at the time of hatching.

The embryo lies transverse to the long axis of the egg until the sixteenth day when it shifts in position so that it lies parallel to the long axis. On the twenty-second day the embryo is in the following position: the head and bill lie along the top of the right thigh, with the bill tucked up against the belly and the right foot curled on top of the head. This position is followed by the pipping position, in which the right wing lies flat over the face of the embryo. The bill protrudes from under the right wing at the angle between the wing and the body and the pipping tooth is brought into contact with the egg shell.

In 1938 and 1940 several 19-day embryos were found with the head upside down and the underside of the lower mandible exposed when the egg was decapped. Whether or not this is normal is not known.

During the four years in which we examined embryos of wild partridges only one nest contained chicks that did not hatch because of an obvious physical abnormality. The two chicks were about 23 days old and were fully feathered, but one had no upper mandible and hence could not pip free of the shell. The mandibles on the other were shortened and hawk-like, and the upper mandible crossed the lower on the left side. This embryo lacked a pipping tooth. (Fig. 10.)

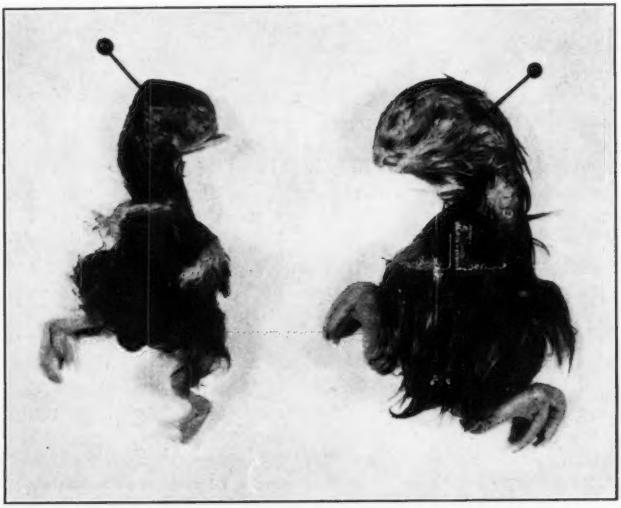

Fig. 10.—Abnormal embryos unable to cut free of the egg shell.

Three hundred embryos were examined during this study, but the material was not distributed equally over all the days of the incubation period. Most of it fell into the last two-thirds of the incubation period; however, no single day had less than five embryos from which to draw the age criteria.

The following is a summary of characters showing the daily development of the Hungarian partridge embryo.

SUMMARY OF AGE CRITERIA IN THE HUNGARIAN PARTRIDGE EMBRYO.

Age (in days)	Characters Indicating Age	Figure
1	Embryo almost invisible to the naked eye. Small white streak on the yolk (primitive streak). Circular area around the embryo 11mm across (covers whole yolk by third day).	
2	Blood area appears on the yolk sac; has a diameter one-half that of the yolk itself. Blood vessels not yet distinguishable. "Head" area distinguishable; dark area indicates eye position. Somites visible. Embryo length 5-6mm.	11
3	Embryo still small but now curved or "humpbacked." Beating heart visible. Blood area enlarging. Embryo length 6-7 mm.	11
4	Posterior lobe of head forming. Pigment develops on top of eye. Large blood vessel down the side of the embryo. Somites still visible. Embryo length 7-8mm.	11
5	Embryo still humpbacked. Outline of eye clearly defined. Optic cup of eye not closed at the bottom. Head has two distinct lobes. Embryo length 9-10mm.	11
6	Limb buds clearly formed, but adhere to body. Upper limb buds lie below the heart, which is still visible. Head is 1/2 or 2/3 the size of the body. Embryo length 17-18mm. Weight, 0.1gm.	11
7	Little change in shape. Limb buds larger, and now protrude. Blood vessels appear on the head over the eye. Eyes protrude. Head ½ body size. Embryo length 17-19mm. Weight, 0.2gm.	11
8	End of leg enlarges; toes now distinguishable. Upper mandible protrudes; no protrusion in region of lower mandible. Neck and coccygeal region well-defined. Blood vessel extends along the side of neck from base of upper limb to base of skull. Optic cup still open at bottom. Embryo length 18-20mm. Weight, 0.45gm.	12
9	Head becomes finely vascular. Lower mandible developing but does not protrude. Forerunners of toes develop; middle toe extends beyond the other two. Embryo length 19-21mm. Weight, 0.4-0.5gm.	12
10	Lower mandible protrudes, giving the bill its adult shape. Front toes visible but not separated. Hind toe present. Pipping tooth present; although small, it is distinguishable and very white. Cloacal opening well-defined. Embryo length 23-25mm. Weight, 0.5-0.7gm.	12
11	Toes separated; no scales on feet or toenail differentiation. "Goose pimples" (feather papillae) along entire back. Two lateral feather tracts present on coccygeal region. "Thumb" (alula) of wing now separated from the "hand" (manus). Embryo length 26-29mm. Weight, 0.9-1.5gm. Leg and foot, 6mm.	12
12	Live embryo is able to open and close the mandibles and to move its limbs. Embryo on its left side with the bill resting on the belly. "Goose pimples" on dorsal surface elongate and darken at the tips. Optic cup complete. Nostrils formed. Large blood vessel (jugular) on side of neck still distinct. Toes and legs finely scaled. Embryo length 32-36mm. Weight, 1.1-1.5gm. Leg and foot, 7-8mm.	12
13	Auditory opening visible. Both feet, with toes widely spread, lie over the head (position in the egg shell). Skin over eye thickens and develops feather papillae. Feathers growing from nostrils back over the	

SUMMARY OF AGE CRITERIA IN THE HUNGARIAN PARTRIDGE EMBRYO—Continued.

Age (in days)		Figure
	head. Dorsal feather tract extends from base of skull to tail. Wings rest along the side of the body with tips over the belly. Embryo length 38-42mm. Weight, 1.2-1.7gm. Leg and foot, 11mm.	12
14	Position in the shell at this general stage: embryo on its left side, head bent forward so bill is between the legs; both feet on top of head; tips of the wings against the thighs. "Goose pimples" on ventral surface elongate into down feathers. Small patch of minute black feathers under and behind the eye. No feathers on the manus. Blood vessel on the neck still visible through the feathers. Embryo length 40-44mm. Weight, 1.8-2.4gm. Leg and foot 12-14mm.	13
15	All feather tracts widen; breast has short white feathers. Pipping tooth has a sharp barb pointing forward. Feathers first appear on the manus. Embryo length 42-46mm. Weight, 2.0-2.5gm. Leg and foot 13-16mm.	13
16	Dark feathers encircle the eye. Embryo changing position from crosswise to lengthwise of long axis of egg. Embryo weight, 3.0gm. Leg and foot 16-19mm.	13
17	Many white-tipped feathers appear on ventral surface of the body. Tips of toenails take on a whitish cast. Embryo weight, 3.5-4.5gm. Leg and foot 19-21mm.	13
18	Yolk sac now shrunk to 1/4 of decapped area. White feathers appear under lower mandible. Eye "lashes" present. Foot webbing at base of toes slight but distinct. Large blood vessel visible down the inside of each leg. Embryo weight, 4.5-5gm. Leg and foot 21-22 mm.	14
19	Yolk sac now shrunk to 1/5 decapped area. Side of head and part of eye visible (previously obscured by yolk sac). Bill appears horny and becomes dark colored. Toenails darken at base. Embryo weight, 5.5-6.5gm. Leg and foot 22-23mm.	14
20	Position in the shell at this general stage: embryo on its side, head slightly down so only side of head is visible from above; part of left leg becomes visible; both feet are over the head. Yolk sac shrunk to 1/10 of decapped area. Hardening of upper mandible is complete; lower mandible is 3/4 hardened. The lower two wing joints (radius-ulna and manus) still lie along the thigh. Embryo weight, 6.5-7.0gm. Leg and foot, 23-26mm.	14
21	Little change in position from 20-day embryo. Yolk sac 1/10 of decapped area. Head completely feathered—to minute corners of the bill and nostrils. Embryo weight, 6.5-7gm. Leg and foot 26-27mm.	14
22	Head and bill against right thigh; tip of bill tucked against belly. Right wing begins to work over the right side of head and bill. Right foot on top of head; left foot on left side of head behind eye. Blood vessels on inside of legs no longer visible. Bill and legs take on horny cast. No yolk sac seen from above. Embryo weight 7-7.5gm. Leg and foot 27-29mm.	14
23	Back of embryo is arched into pipping position; right wing lies over right side of head so that the bill protrudes from under the wing. The bill is dry and the pipping tooth rests against the shell. Shell membrane is pierced. Yolk sac the size of a nickel. Feet in same position as of 22-day embryo. Pipping begins (egg is cracked or bulged at start of pipping). Embryo weight (with yolk sac) 8-9gm. Leg and foot 29-30mm.	14
24	Egg from 1/5 to 4/5 pipped (peeping can be heard if the chick is alive). Position of embryo same as that of 23-day. Yolk sac is 1/2 the size of a nickel. Embryo weight (with yolk sac) 8.5-9.5gm. Leg and foot 30-32mm.	
25	Birds hatch.	

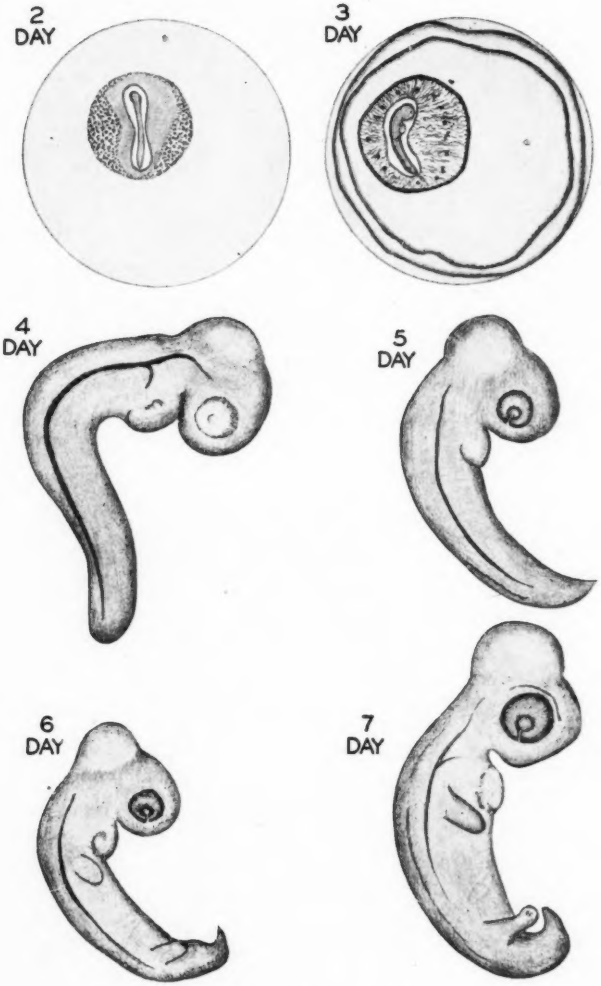

Fig. 11.—Hungarian partridge embryos 2 through 7 days.

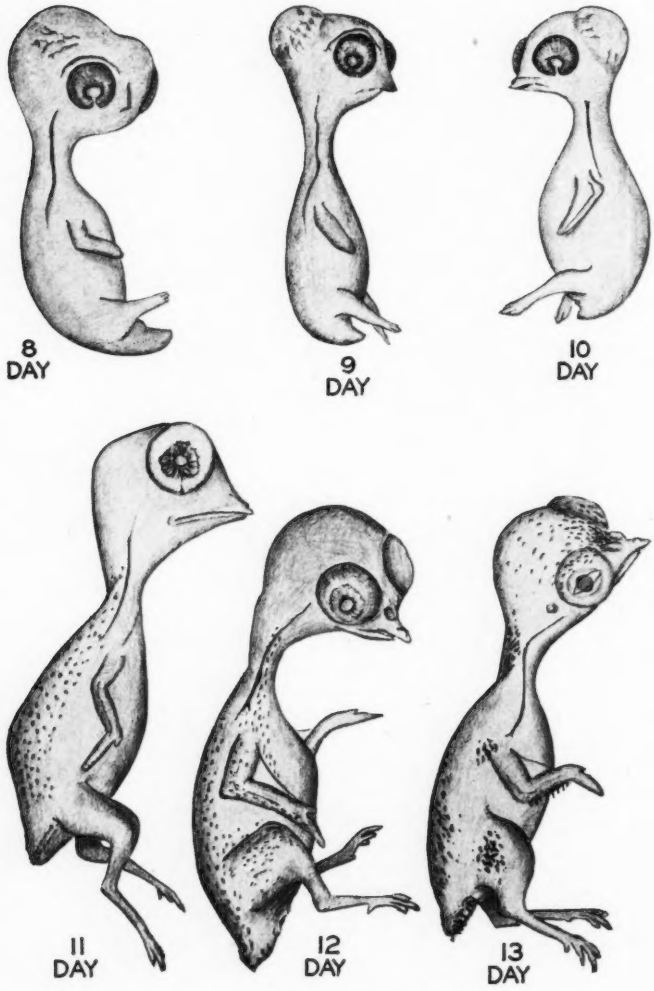

Fig. 12.—Hungarian partridge embryos 8 through 13 days.

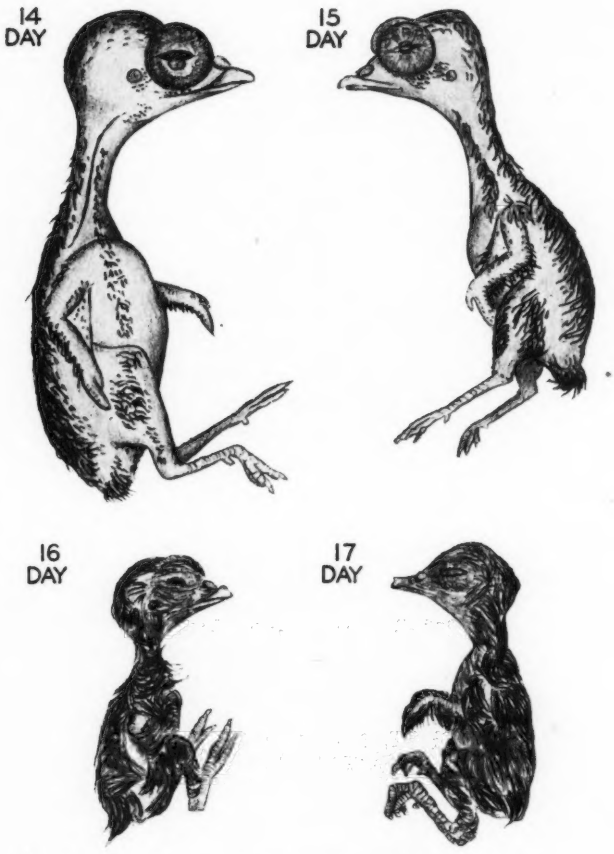

Fig. 13.—Hungarian partridge embryos 14 through 17 days.

It must be remembered when using these embryo characters as a key for dating the first egg or hatching, that live embryos differ in certain respects from dead embryos of the same age, e.g. blood vessels may not be evident in dead embryos, disintegration of the skin may obliterate feather papillae, and leg scales.

The excretory sac (allantois) was found to adhere tightly to the egg shell and so caused little difficulty in the weighing of the embryo. The total length of the embryo was taken as a crown-rump measurement of the relaxed specimen,

that is, the specimen was neither stretched nor allowed to remain in a doubled-up position.

Post Nesting: the Chick

AGING OF CHICKS

In order to find out at what age the wing sex character became reliable and to check molt and chick behavior, about 150 partridges were raised in pens. During the summers of 1941 and 1942, 13 complete broods were studied at the Mound View pheasant farm at Lake Mills, Wisconsin. Also 15 incubator-hatched birds were raised at the University of Wisconsin Arboretum in 1943.

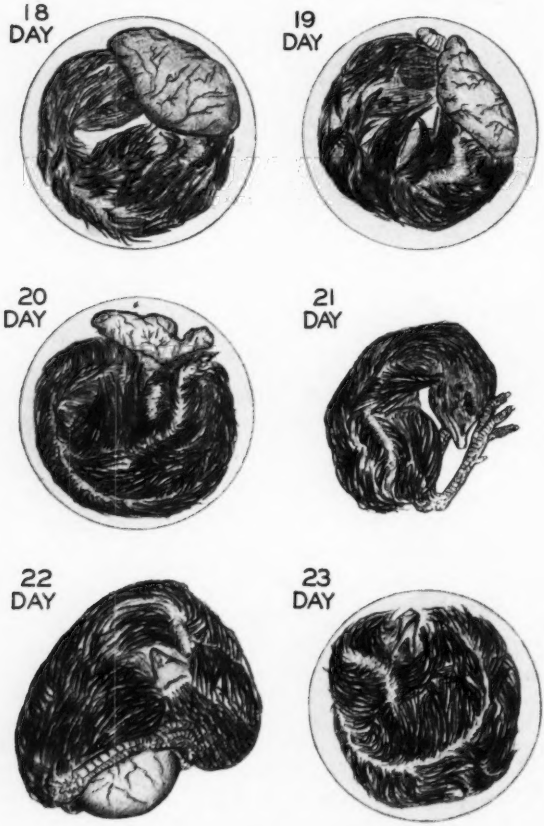

Fig. 14.—Hungarian partridge embryos 18 through 23 days.

It is difficult to raise partridge chicks without experience and the best in equipment, as anyone who has tried can testify. Our methods of rearing were variations of those discussed in the game farming literature. Bantam hens hatched the clutches. An adaptation of the single compartment quail pen was used in raising the chicks. Later the juvenile birds were transferred to roofed holding pens. Observations and measurements were made throughout the rearing period.

Plumage.—Field observations and examinations of road kills and skins of juvenile wild birds lead us to believe that the wild birds complete each molt in less time than do pen reared birds. Each subsequent complete plumage appears therefore to be held for a greater length of time by the wild birds.

Soon after the down is completely dry on a newly hatched chick, certain plumage characters are evident. Most of these have been ably described by Roberts (1932: 540-541), and may be summarized as follows. Three colors, brown, black, and buff, are predominant, each in various shades. The top of the head, lower rump and wings are rufous. The sides of head and neck are yellow-buff shading into gray-buff in the breast and belly. The back of the neck is the same as the breast. The back is mixed brown and buff, usually marked with two black lines extending from the base of the skull to the rump.

The acquisition of the juvenal plumage does not appear to have been carefully described in any American publication. Dr. A. S. Leopold advises us that L. Bureau thoroughly covered moult sequences in the partridge in 1911 (*L'Age des Perdix,* 1. *La Perdis Grise.*—Nantes), but we have found this reference to be virtually inaccessible. The first feathers of the juvenal plumage are the remiges of the wing. The first seven primaries (Nos. 1 through 7) appear between the second and fourth days. The secondaries appear between the third and sixth days. The sequence of replacement for the primaries is shown in Fig. 15. No. 8 primary, the last to appear, grows very slowly, appearing first at 13 weeks, and is completely grown at 18 weeks. The slow development of the eighth primary is also shown for the rock ptarmigan (*Lagopus mutus*) (Salomonsen, 1939: 54) and the wild turkey (Meleagris gallopavo) (A. Starker Leopold, 1943: 135).

A shagginess of the natal down heralds the approach of the underlying juvenal feathers. The shagginess is first noticed on the underside of the neck and on the breast where the ventral tract is starting to develop. The development takes place between the seventh and tenth days and appears to develop posteriorly. The scapulars and the wing coverts are next to appear, usually present betwwen the eighth and twelfth days. The tail also develops during this period, and is complete between four and five weeks, at which time the post juvenal molt of the tail begins. The rate of replacement was not tallied, but it begins from two foci (rectrix No. 3) and spreads laterally in the following order, 3-4-2-5-1-6-7-8-9. The feathers first replaced grow rapidly and the post juvenal feathers in the middle of the tail may be 6.5 cm. long before the outer two juvenal rectrices are shed. All juvenal feathers are replaced between 10-11 weeks and the post juvenal tail is completely grown by 14 weeks. The scapulars are difficult to observe but appear to spread forward and backward from a central point in the tract.

The spinal, head, crural and femoral tracts are last to shed the natal down. The spinal tract develops between the fifteenth and twentieth days. It was found to start anywhere along the mid-dorsal line as a thin stripe developing anteriorly or posteriorly before spreading laterally to cover the back. The crural and femoral tracts also develop posteriorly during this interval. The head tract is last to molt (between 20-25 days). It starts with the development of a mid-dorsal stripe of new feather quills and spreads laterally like the spinal tract, and posteriorly. Next the chin feathers appear, first at the edge of the bill, also developing backward. Finally, the cheeks and areas around the eye molt. Some natal down may be present there when the rest of the body is entirely clothed in juvenal plumage.

The juvenal plumage is a drab gray-brown; both sexes have the same colors and feather markings, which in general resemble those of the adult female. The complete juvenal plumage may be described as follows: The top of the head is dark, covered with small black feathers having brown tips and buff rachises. The chin is gray shading to mud-brown along the ventral surface. The back is also covered with many thin mud-brown feathers that have a heavy, downy,

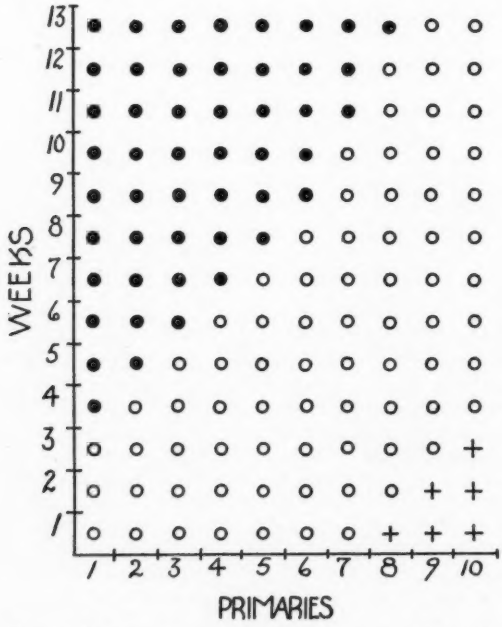

Fig. 15.—Rate of feather replacement in the Hungarian partridge wing. The white circles indicate juvenal feathers, the black circles post-juvenal feathers, and the crosses represent feathers not yet grown out.

gray aftershaft. The tail is a faded rufous color, its coverts tan with brown cross-barring. The wing color varies between individuals: the primaries and secondaries are gray-brown with tan markings, the scapulars are black or dark brown edged in tan, with a tan rachis and cross-barring. All scapulars and coverts are cross-barred in tan. All feathers except those of the wing are thin and lace-like; especially is this true of the crural and femoral tracts. The most conspicuous character of the plumage is the light stripe running down the rachis of each feather. This is most pronounced on the neck and breast.

The complete juvenal plumage is usually attained at six weeks. The post-juvenal plumage develops immediately and often before the previous molt is complete. The sequence of replacement is the same as that when the juvenal plumage replaces the natal down. The post-juvenal plumage is that which the bird wears during its first winter, and is identical in appearance with the true adult plumage (second winter) except that the ninth and tenth (outer 2) wing primaries of the juvenal plumage are retained the first year. The post-juvenal molt is easily observed because the new darker feathers contrast with the faded juvenal plumage (Figure 16). This molt brings out the sex markings on the median and lesser wing coverts and scapulars. These feather tracts need not be complete for sex determination; the first few feathers which appear, even though they be patchy and in no special pattern, suffice to determine the sex of the bird.

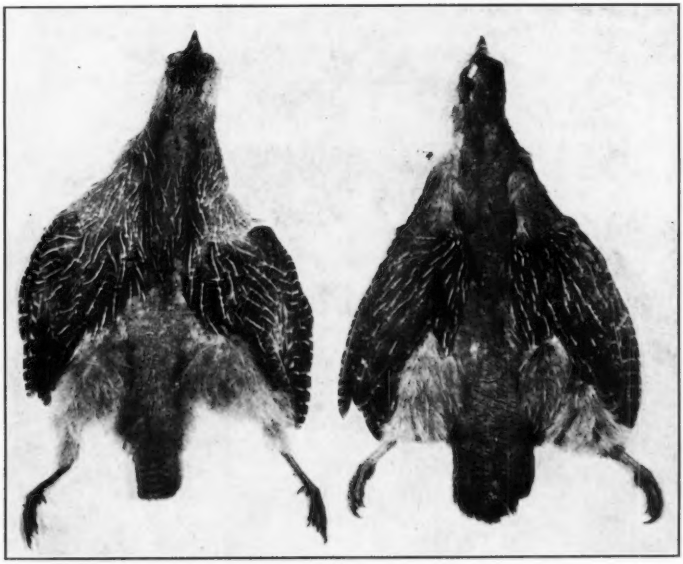

Fig. 16.—Flat skins showing differences between the juvenal (left) and post-juvenal (right) plumages.

The "horseshoe" breast barring, the buff and halo of the head and the red glands behind the eye are present in both sexes after the post-juvenal molt and help to distinguish early from late broods for a short period in early fall. The horseshoe barring is formed by the dark brown feathers on the inside of the left and right branches of the ventral tract. This barring will be discussed further under *Sex Determination*. The red glands behind the eye are wart-like growths that turn red in late autumn. The eye glands are vermillion in the cock and much less intense in color in the hen. The halo is a stripe of white feathers which runs from the back of the skull around the front of the head, forming an almost complete circle. It separates the buff of the front and sides of the head from the darker crown feathers. Good pictures of the halo appear in Askins (1931: 121) and in Heinroth (1928: 3: 256).

General characters.—The aging character most widely used, especially in England, for distinguishing adults from first year birds is the condition of the ninth and tenth (outer two) wing primaries (Figure 17). If these are faded (Portal-Collinge, 1932: 15) and rounded at the tip (1936, I. C. I. Bull. no. 9: 3), the bird is said to be at least a second year bird. If the primaries are pointed and not faded it is said to be a bird of the year. We do not believe this method to be reliable enough for accurate aging of individuals. Color of feathers is particularly deceiving: several of our pen-reared birds were naturally faded looking and yet were as young as those with brighter wing feathers.

A character accurate both for individuals and for large samples is the presence of the bursa of Fabricius which indicates that the partridge is a juvenile, since the bursa is lacking in an adult (Gower, 1939: 427). We used this

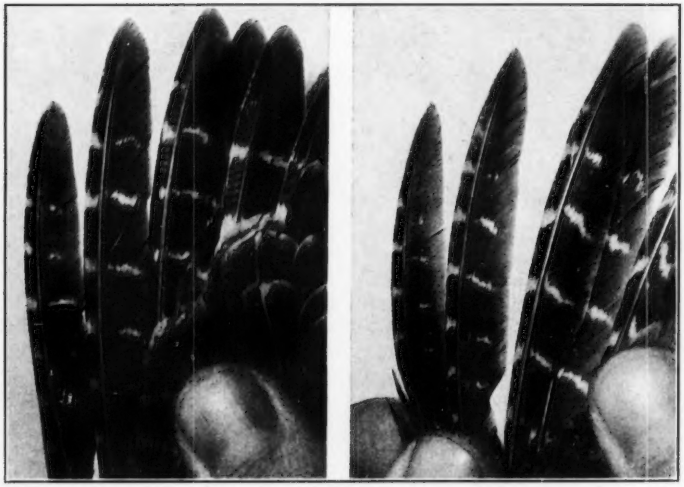

Fig. 17.—Rounded primaries 9 and 10 of an adult (left); pointed primaries 9 and 10 of a bird of the year (right).

aging method on a number of dead specimens. The exact age at which the bursa disappears in wild Hungarian partridges, however, is not known, but we know it is present to January 1 in some young.

While the bursa distinguishes between birds of the year and those older, in working with any game bird it is often desirable to know the age of juveniles. To this end we raised 65 Hungarian partridge chicks in three different years and in ten different age groups, and recorded their development.

All birds were weighed and measured weekly and feather tracts and appendages were separately recorded as to length, spread, color, and shape. It soon became evident that feather measurements (tail and wing) were impracticable because of breakage due to confinement. Most weights were invalidated by artificial diet and extreme individual differences (Figure 18). Plumage appearance and the measurement of the combined tarsus and middle toe with claw

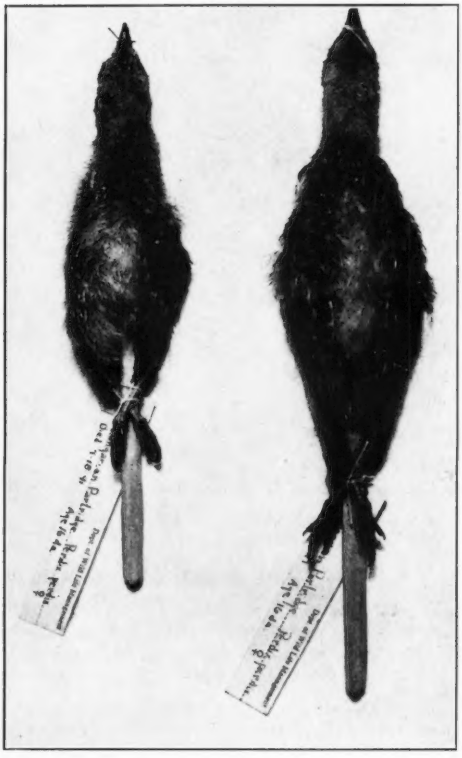

Fig. 18.—Size differences in pen-reared chicks of the same age (16 days).

proved to be the most reliable age indices. After 25 weeks of observations, during which time 60 per cent of the birds died, 27 Huns were raised to full post-juvenal plumage. A ventral view of the natal down, juvenal, post-juvenal and adult plumages is shown in Figure 19.

The following table summarizes the distinctive age characters for our penned partridges. We do not know how much this departs from development in the wild, but if it departs, the rate of development is doubtless slower for the penned birds. The 1943 group, we believe, developed at the same rate as do most wild birds. Their ultimate weights were the same as the average wild weight.

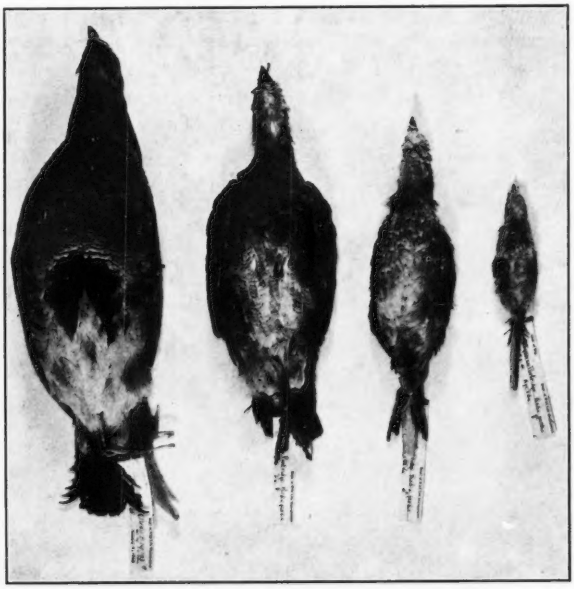

Fig. 19.—Adult, post-juvenal, juvenal and natal plumages of Hungarian partridges.

WEEKLY DEVELOPMENT OF THE HUNGARIAN PARTRIDGE CHICK.

Age (in weeks)	
1	Pipping tooth present during first 24 hours. Wing primaries 2-10mm. Chick entirely downy (except alar feather tract). Leg and foot 35-39mm.
2	Juvenal tail feathers grown from 1-10mm. Juvenal scapular feathers grown from 1-8mm. Juvenal breast feathers (ventral tract) just beginning to appear. Leg and foot 40-47mm. General appearance shabby. Tail flicking becomes evident as soon as there are tail feathers.

WEEKLY DEVELOPMENT OF THE HUNGARIAN PARTRIDGE CHICK.—Continued

Age (in weeks)	
3	Juvenal feathering on the back (dorsal tract) from rump to area above the shoulders. Feathers of the breast well developed. Leg and foot 47-55mm. General appearance: the bird appears to be at the halfway point in the juvenal molt.
4	Juvenal feathering present on the head (head or capital tract), along the median stripe and on the sides. Leg and foot 55-60mm. General appearance: feathers of juvenal plumage well-developed. Head region looks shabby and may have patches of natal down around the eye. The chick peep is beginning to change into an adult-like call.
5	Head completely covered with juvenal plumage late in this week. First winter plumage developing at the base of juvenal feathers—noticeable along the back and wings. Leg and foot 60-65mm. General appearance: the bird is now in complete juvenal plumage. The beginning of the post-juvenal molt is not apparent without close examination.
6	Post juvenal molt now visible along the wing, both primary and secondary feathers. Leg and foot 65-73mm. General appearance: the bird appears fully feathered until it tries to fly, then the shed wing feathers are noticeable. The adult call is now used about half the time.
7	The post-juvenal molt is now affecting the tail. Wing primaries continue to molt, while the new feathers grow and develop. Leg and foot 73-80mm. General appearance: wings mottled with juvenal and "first-winter" plumage. The tail now has 3 or 4 juvenal feathers on each side and beginning post-juvenal feathers in the center.
8	Neck area (upper ventral tract) molting. Leg and foot 77-82mm. General appearance: bird slightly larger than an adult quail; is shabby-looking with the post-juvenal molt about one-half complete. The body carriage is adult-like.

The post-juvenal molt is a slow one and although weekly measurements were made, differences were slight. Further diagnostic age characters are as follows:

9	Wing coverts and scapulars develop enough for reliable sexing.
10	The buff feathers of the head begin to develop. Leg and foot 82-86mm. No further growth.
11	The cinnamon-colored "horseshoe" of the breast begins to appear.
12	The white "halo" feathers develop on the head.
13	Red eye glands appear. The post-juvenal molt is complete.

PTERYLOSIS

Closely allied to the study of molt in any avian species is its pterylography. Figure 20 shows the feather tracts as deduced from 20 adult specimens plus a number of juveniles. The names of the various tracts (pterylae) are those used by Sclater (1867: 16-17). The featherless areas (apteria) are complements of the pterylae and will not be discussed. The names and descriptions of the various tracts follow:

1. The Head Tract comprises all the feathers of the head and is continuous with the spinal and ventral tracts. The partridge has a featherless area

around each eye and extending about 10 mm behind. The nasal fossae are also bare of feathers.

2. The Spinal Tract consists of the feathering of the back from the nape of the neck to the tail. The portion of the tract on the neck is strong but narrow, widening at the shoulder blades and tapering again slightly above the tail. This tract is continuous and is not divided longitudinally.

3. The Caudal Tract includes the rectrices and the upper and lower tail coverts. Eighteen is the usual number of rectrices, although several specimens had only 17. The tail is round and the average length is 82mm.

4. The Crural Tract is made up of the feathering on both legs, and is therefore a double tract. The feathering covers the lower part of the leg along the tibia. It is strongest just above the tarsus and is very weak below the "knee." It is also weak on the inside of each leg.

5. The Femoral Tract, as the name implies, comprises the feathering of the upper portion of the leg (thigh). It is a very strong tract, distinct from the crural and spinal tracts, although the space between the femoral tract and the spinal tract is sometimes not entirely free of weak extensions of both tracts. The femoral tract is also very strong in its early development on the embryo (Figure 12.).

6. The Humeral Tract, which is double, is a short band that extends from the middle of the shoulder running over the humerus parallel to the spinal tract. The feathers of the humeral tract are the scapulars. This pteryla is strong and cleanly separated from both wing and spinal tracts.

7. The Wing Tract, also double, includes all feathers of the wing, not to be confused with the humeral tract. In the specimens examined the wing primaries numbered ten and the secondaries 13. The third primary is usually the longest. The alula (bastard wing) has four feathers.

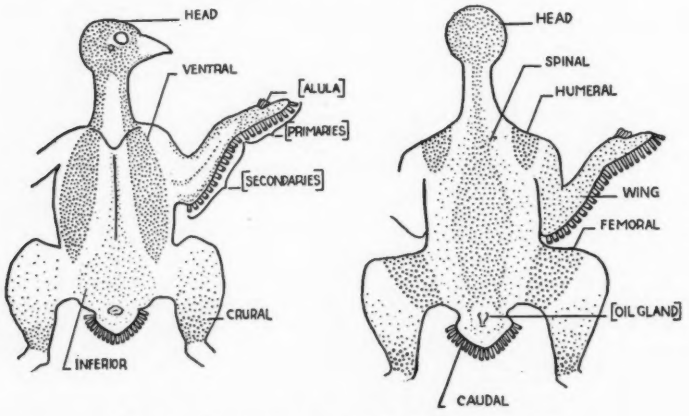

Fig. 20.—The pterylography of the Hungarian partridge.

8. The Ventral Tract is a strong, branched, lanceolate tract that arises at the chin and extends down the neck and over the breast to a point on the side just above the abdomen.

9. The Inferior Tract which begins at the throat is very weak and thin. It is divided along the sternum but then fuses and becomes stronger and wider, covering most of the abdomen. It is distinctly separated from both branches of the ventral tract.

The oil gland is a heart-shaped organ located at the base of the tail. There is a circle of small feathers at the proximal end. The area surrounding the root of the gland is featherless.

WEIGHT GROWTH OF CHICKS

The growth rate of Hungarian partridges was impossible to get from the wild. Growth rates were therefore determined from 65 pen-reared chicks, weights of which were taken weekly. The birds were weighed as early as seven hours old and some as late as 154 days. The 65 birds came from two sources: first, in 1941, eggs from mowed-over wild nests were hatched by bantams and raised at Lake Mills, Wisconsin; second, a group from pen-reared stock hatched

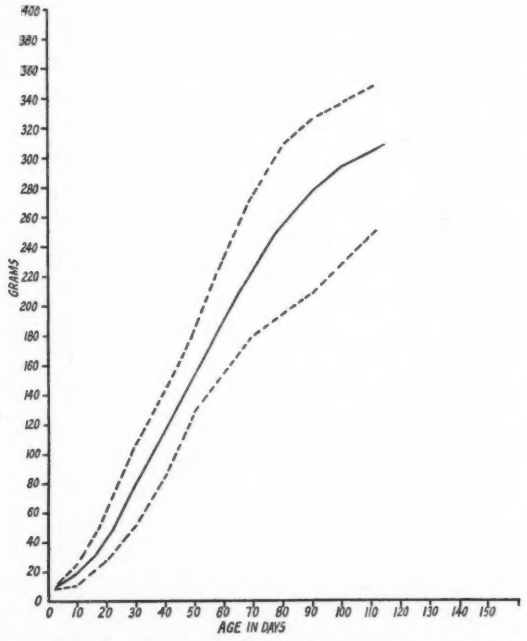

Fig. 21.—Weight curve of (subnormal) Hungarian partridge for 1941; broken lines show range of individual weights.

at the State Game Farm was raised at the University of Wisconsin Arboretum in 1943.

Marking of individual birds had to be done in a series of steps as the birds grew. Combinations of colored string were first used, then colored celluloid sparrow bands, and finally colored celluloid small-gamebird bands or numbered metal bands.

Individual birds and broods varied in weight oftentimes for no apparent reason. From a study of the individual weight curves it is evident that if a chick was below average at four weeks, it remained below average even as an adult; that if an above-average bird fell below average it usually regained its former status when a young adult; that birds severely feather-picked were always underweight. The average weight curve of the 1941 birds giving the range of weight disparity among individuals is shown in Figure 21. Although regular weighings were discontinued at 120 days, a subsequent weighing showed that the curve leveled off at 355 grams. The 1943 average weight curve is shown in Figure 22. These birds were received from the Game Farm at three

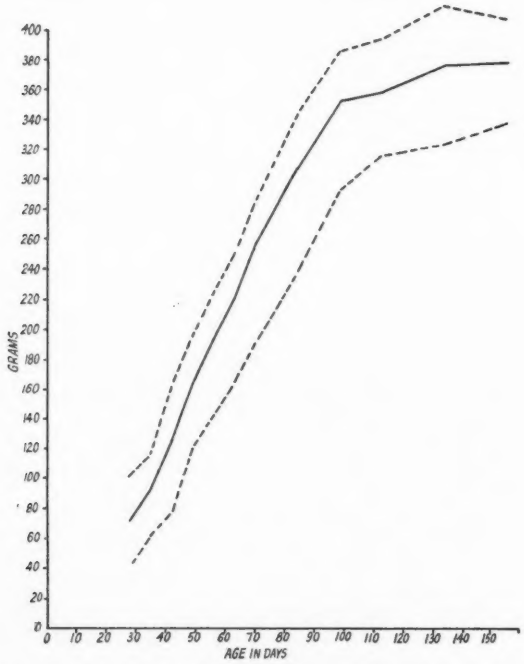

Fig. 22.—Weight curve of Hungarian partridge for 1943; broken lines show range of individual weights.

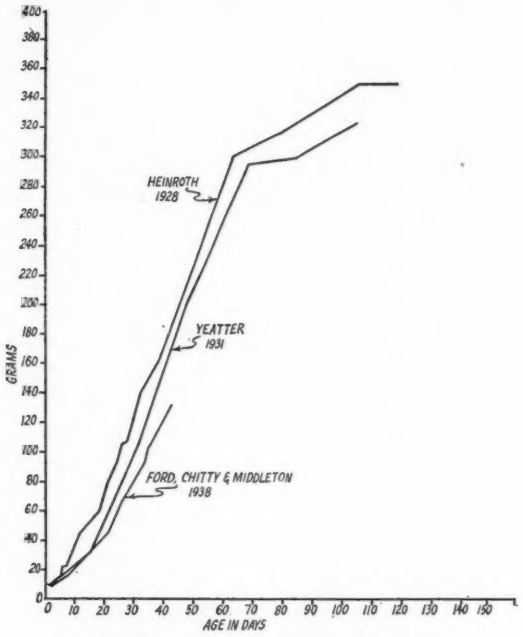

Fig. 23.—A comparison of partridge weight curves.

weeks of age and were first weighed at four weeks. The curve leveled off at 380 grams.

We found the average weight of an adult wild Hungarian partridge to be 385 grams. It is therefore evident that our 1941 group was poorly developed, while the average weight attained by the 1943 group was equal to the average wild weight. The 1943 birds happened to be all females and yet were only 5 grams under the average weight of a combined sex group.

Heinroth (1928: 239), Yeatter (1931: 37), and Ford, Chitty and Middleton (1938: 253) have also periodically weighed young partridges, and their results are shown on the same scale as ours in Figure 23. Heinroth, in Germany, raised three birds from eggs of a wild European partridge. These birds were raised indoors in an aviary and were weighed 28 times in 119 days. Half of the weighings were made in the first 16 days. Yeatter weighed 9 to 11 birds 7 times in 110 days at the Michigan State Game Farm. Ford *et al.* working in England took the average weights of four groups of pen-reared partridges which were weighed 23 times in 42 days. The numbers in the groups were not given. The Heinroth and Yeatter birds showed early rapid development and the weight curves of those groups began to level off at 300 and 294 grams respectively. The Ford *et al.* curve, although carried only to six weeks, was nine days

slower in development than the two aforementioned groups at 42 days. Our two curves are practically identical with the Ford *et al.* curve up to this point. The 1941 weight curve tapered off instead of flattening abruptly. This curve shows decidedly poor development after six weeks, and the birds never attained true adult weight. The 1943 weight curve displays normal development but was 16 days behind the Heinroth and Yeatter curves at their leveling off weight of about 300 grams, and did not level off until it had reached 352 grams. In no other case did we find any pen-reared birds reaching adult wild weights. How the true wild weight would compare with any of the curves discussed is a matter for speculation, but we believe our 1943 curve to be accurate in mode of development but about ten days delayed in rate.

SEX DETERMINATION

The sex of an adult partridge can be determined by the scapular and median wing coverts, as Yeatter (1934: 12) and others have shown. The adult male can be distinguished from the female by its darker "shoulder" feathers, which have a single median buff stripe. The female has lighter covert feathers with a wider buff stripe and two to four buff crossbars (Fig. 24). The male usually has a bright rust colored head and is more agressive in its behavior.

Fig. 24.—Secondary wing coverts of female (left) and male (right) Hungarian partridges.

The cinammon colored "horseshoe" feathering on the breast is not considered by most writers to be an infallible sex criterion. The various types of breast feathering are worthy of further clarification. It was once thought that the female had a white horseshoe marking, or no horseshoe at all, and the male a dark brown marking. These extremes of all-white or all-brown horseshoes have been observed in this study on the female and male respectively. There are, however, many confusing intermediates. Figure 25 shows a female with an all-white horseshoe on the extreme left and a male with a corresponding all-brown marking on the extreme right. The three birds in the center of the figure are all first-year females with the markings of various intensity. It is this intermediate group that nullifies the horseshoe as a sex criterion.

We thought that the brown feathering of the intermediate female would probably be lost after the post-juvenal plumage was shed. Of six pen-reared females under observation all retained the brown barring after the molt. Saunders and Clarke (1927: 800), contrasting the white and brown horseshoe of the partridges, state, "In some parts (of England) the tendency to a 'white

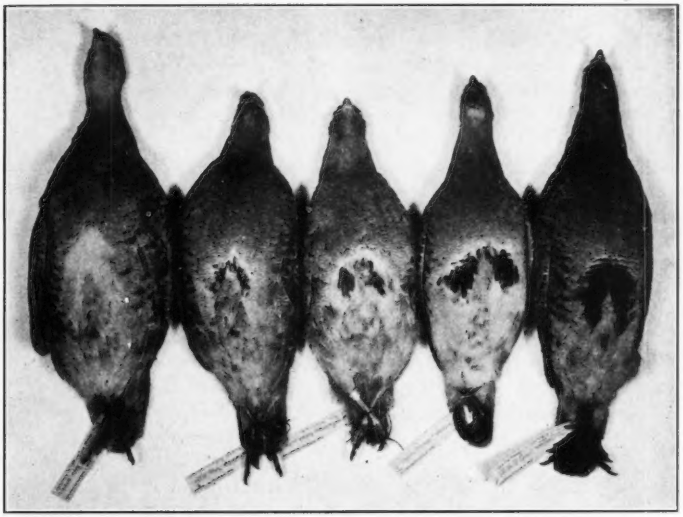

Fig. 25.—Horseshoe breast feathering varying from all-white to all-brown. The only male specimen is at the extreme right.

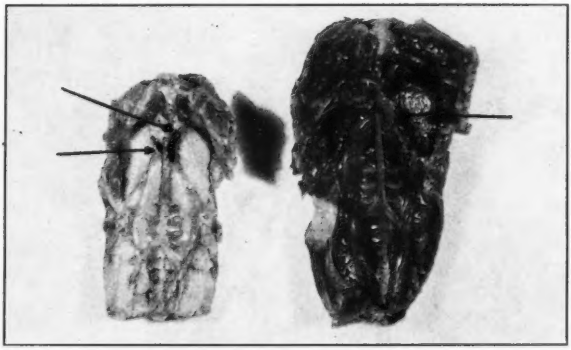

Fig. 26.—Hungarian partridge gonads. Four-week-old ♂ on the left, six-week-old ♀ on the right.

horseshoe' is apparent, perhaps due to the introduction of Hungarian birds; while a 'black horseshoe' has been found." Pollard (1930: 69) shows by illustration the presence of both a white and a brown horseshoe.

Dissection was the only method by which the sex of embryos and chicks could be determined. A juvenal-plumage sex character could not be found. The testes of a chick were often black or speckled with black, when examined several hours after death, while birds opened soon after they died had white testes. This darkening of the testes was not checked with a large number of specimens and it is possible that the gonads had not undergone a change at all. Nevertheless dead chicks were not examined for twenty-four hours so that the testes could be more easily located. Fig. 26 shows the gonads of a male and female chick of four and six weeks respectively.

In sexing embryos the opening is made along the mid-ventral line to prevent cutting into the sex organs. The intestine must be carefully removed so that the gonads are not torn away from the kidneys. Embryos, if fresh, can be sexed with a hand lens or dissecting microscope as early as twelve days. Embryos younger than twelve days can be sexed only by sectioning.

An embryo to be sectioned is first placed in Bouin's fixative. The genital regions of the embryos are removed, dehydrated with dioxan and imbedded in paraffin. They are then sectioned at ten microns, stained with Heidenhain's iron hematoxylin, counter-stained with water soluble eosin, and covered with glass cover slips.

A male and a female section for 7, 9 and 11 days are shown in Fig. 27. In this figure the 11-day embryo was photographed under low-low magnification, the 9-day embryo under regular low, and the 7-day embryo under oil immersion. Obviously the gonads would be larger in the oldest embryo, but the magnification in the photographs reverses this size order in the respective fields.

The 9- and 11-day photomicrographs show the dorsal side of the embryo at the top. The gonads are in the center of the field in all four pictures. Toward the top of the photos at 11 days we see the dorsal nerve cord which is slightly rectangular and hollow (part of it is cut off). Below this is a circular area with two lateral wings and a light center, which is the embryonic backbone. Below the backbone is another circular area partly filled with stained material (red blood cells) which is the dorsal aorta. The spongy-appearing tissue on either side of the gonads is the kidney tissue. The 11-day photo also shows dark liver tissue (lower left), a section of spleen, and a section through intestine (lower left). The 9-day photos show only the dorsal aorta at the top. The testes are clearly defined, and the ovaries are just to the left and right of the light stripe in the center of the field. The ovary tissue is more compact than that of the kidney in which it is embedded. The right ovary is smaller and slightly anterior. The 7-day gonads show only a section of the outer edge of the gonad proper, hence the entire field is highly magnified gonadal tissue.

The sex of the eleven-day pair is easily determined because (1) the ovaries are asymmetrical (the right ovary is about one-fifth the size of the left, whereas the two testes are about equal in size, the right testis being slightly smaller); (2) in cross section the testes are clearly oval while the left ovary is kidney-

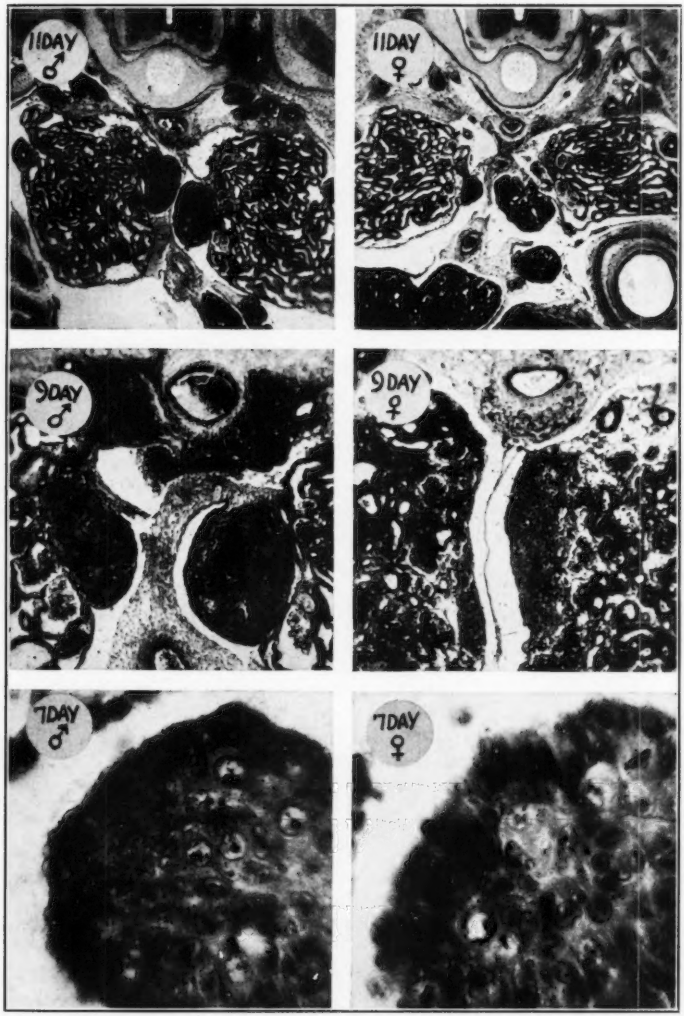

Fig. 27.—Cross-sections through the gonads of male (left) and female (right) embryos.

shaped and the right is shapeless ;(3) the structure of the testes shows a series of tubules (light areas within the testes), while the ovary is divided into two regions, a thick outer cortical region and an inner medullar portion containing distended empty tubules.

The nine-day specimens show the same distinguishing features as do the older pair. The shape of the gonads is the most striking—the ovaries are flat organs and the testes are oval. The asymmetry of the ovary is noticeable at this stage, and the structure of the tubules of the testes and the granular appearance of the ovaries is also very clear.

The seven-day sections must be examined more carefully, since it is difficult even with good material to be absolutely certain of sex. The only species with which we can make early embryonic comparisons is the domestic chicken. Swift (1915: 459) states that there are three reliable criteria in the determination of the sex of the chick embryos at seven days. "These are: the relative size of the two gonads, the germinal epithelium, and the number of primordial germ-cells in the germinal epithelium." The first means that although the right gonad is smaller than the left in both sexes, this difference becomes more pronounced with age in the female.

By germinal epithelium is meant that the epithelium of the left gonad of the female is several layers thicker than that of the male. In the ovary, primordial germ cells are largely limited to the germinal epithelium, but in the testes these germ cells have been carried into the medullary region beneath the epithelium. The criteria for sex differentiation are about the same for the Hungarian partridge as are described by Swift for the chicken.

Several six-day embryos were also sectioned but no sex differences could be noted. It appears therefore that the sex of the Hungarian partridge and the chicken (6½ days, Swift, 1915: 459) is differentiated at about the same time.

The sectioning method of sexing, which is not newly described here, should be of value to game bird biology in two ways: first, in obtaining complete sex ratio figures for a clutch or given group of eggs; and second, in the investigation of differential die-off of sexes before hatching. In this study the complete sex ratio of clutches was obtained by the sectioning method, but no research was done with pre-hatching mortality.

SEX RATIO

Sex ratio as we will use the term is defined by Mayr (1939: 156). The primary sex ratio, that at the time of fertilization, will not be discussed. The secondary sex ratio, or that at hatching, will be compared with the adult or tertiary sex ratio.

Our secondary sex ratio figures were arrived at by two methods: (1) the sexing of chicks from salvaged clutches hatched with a bantam or incubator; (2) the sexing of embryos which had died by unnatural means such as desertion and mowing. No embryos that died naturally in the shell were used in sex ratio data. The percentages of natural embryonic deaths for all nests are as follows:

1938	1940	1941	1942
0.5%	3.2%	3.0%	1.4%

There is a possibility of error since some of the "unnatural death" embryos might have died before hatching in any event, but the above percentages indicate this error to be insignificant. Moreover, more than half of the sex ratio data were determined from hatched chicks.

The few embryos that normally die in the shell are often impossible to sex because incubation speeds up decomposition. Whether there is a differential sex die-off in these embryos is speculative. The accumulated data on secondary sex ratio as presented in Table 12 show females predominating (57%).

In pheasants a predominance of females in the secondary sex ratio was found by Latham (1942: 7). Landauer and Landauer (1931: 495) and Byerly and Jull (1935: 217) writing on the secondary sex ratio in the domestic chicken indicate a secondary sex ratio favoring the female.

If mortality factors affect the male and female alike we should expect to find the secondary and tertiary (adult) sex ratios similar (McIlhenny, 1940: 89), but we did not find this to be the case. Of 115 adult partridges examined, 58% were males. Because of the small sample, this percentage is not significantly different from a 1:1 ratio. However, the change from 43% males in the secondary sex ratio (Table 12) to a 1:1 ratio in adults is important. It is evident that a differential mortality occurred between the secondary and tertiary sex ratios that favored the male.

There is almost no information on the secondary sex ratio of game birds. There is some available, however, on the tertiary ratio. Methods of obtaining this ratio differ, but Table 13 presents the data as given by several authors.

TABLE 12.—Hungarian Partridge Sex Ratio (Secondary) at Hatching .

	1938	1940	1941	1942	Totals	Per Cent
No. of eggs studied	677	403	243	179	1502	
No. of embryos sexed	116	30	90	95	331	
Male	56	8	31	47	142	43
Female	60	22	59	48	189	57

To what extent the secondary sex ratio is affected by differential mortality is not known; but we found that Hungarian partridge embryo mortality in over 500 eggs was more common during certain periods of development: one at from 4 to 5 days, another at about 16 to 17 days, and the third between 23 and 24 days. Romanoff *et al.* (1938: 23) found similar periods for the pheasant at 4, 11 and 23 days respectively, and for the quail at 5, 12 and 23 days.

CHICK BEHAVIOR

The newborn Hungarian partridge chick is always a source of amazement to an observer, for although it is not more than two inches high, the chick is extremely quick and is a master at the art of hiding. This makes accurate brood counting in the wild difficult if not impossible. In an effort to under-

stand the behavior of the chick, we studied twelve broods under pen-rearing conditions. Our method of rearing was not new, nor so successful that it needs to be described here, except to say that a light-bulb brooder was used to facilitate better observations of the young partridges.

Sleeping.—Just after the chicks are hatched their time is divided between running around for no apparent reason, and sleeping. Most of the day is given to sleep. Three resting positions were used by the chicks. First, the bird stands and dozes with eyes shut and head nodding. Second, the chick sits down on its haunches with its legs under its body so that the belly and tail region are on the floor. It blinks its eyes a few times, bends its head forward so that its bill also touches the floor, shuts its eyes, and rests. This position is most used and the chick is easily wakened from it. Third is the position that is used in complete relaxation: the bird lies on its side with legs outstretched to the side or back, its head lying on one side and its wings held away from the body. When a chick has assumed this prostrate position, more disturbance is necessary to bring it into action than in either of the other two resting positions, and the bird was often mistaken for dead. In general, the prostrate position was most used when the birds were one to four days old, and the sitting and standing positions were used most after four days.

TABLE 13.—Adult Sex Ratios (Tertiary).

Authority	Per Cent		Numbers	Species
	Male	Female		
Bennett (1938)	59.0	41.0	5,090	Blue-winged teal
This Study	58.3	41.7	115	Hungarian partridge
Stoddard (1931)	53.3	46.7	20,000	Bobwhite quail
Emlen (1940)	52.9	47.1	15,728	California quail
Middleton (1935)	52.4	47.6*	754	Hungarian partridge
Hochbaum (1939)	52.0	48.0	591	Diving ducks
Bump (1932)	51.3	48.7	546	Ruffed grouse
Gorsuch (1934)	50.7	49.3	304	Gambel quail
Yocum (1943)	49.6	50.4	137	Hungarian partridge
Hochbaum (1939)	41.0	59.0	710	River ducks
Buss (1939)	19.0	81.0	112,024	Pheasant

* Taken from combined sex ratio of old and young birds in the hunting kill (Middleton 1935:144).

Feeding.—During the first 24 hours after hatching, a chick makes no effort to eat or drink. The incorporated yolk sac supplies the necessary food. During the second day pecking by the entire brood is noted; the birds peck at anything within range, mostly at each other—toes, nostrils, head, back, and bill. Food placed on the floor is picked up in this all-inclusive pecking process so that enough food is eaten to carry the young bird over the first few days of its life. By that time a learning process develops, and pecking appears selective, although the other pecking is by no means discontinued.

Moving objects were readily pecked at, and birds could be induced to eat by dropping the small pellets on the paper floor of the brooder (age of birds: 2-5 days). As the food pellets hit the paper they rolled and bounced like small

pebbles. The partridges usually chased these down and ate them. This method was not entirely effective but usually worked very well, perhaps in inverse proportion to the amount of food already eaten. Sometimes the pecking on the paper floor caused those pellets nearby to roll; they were then sought after and eaten. The chicks could also be induced to eat if we tapped on the side of the brooder with the point of a pencil to mimic the sound of birds feeding. This worked well at first, but after several times became ineffective.

Live grasshoppers, crickets and beetles were fed to the young birds. Five feedings of insects were treated in the same way by the chicks: the insects were seldom eaten but were fought for and then carried about, dropped, picked up by another bird and relayed around until the insect was dead, lost, or had escaped. On several occasions an insect was pulled apart by two or more chicks, and the parts eaten, but usually all dead insects remained untouched (age of birds: 16 days).

At five weeks, grasshoppers, crickets and beetles were readily eaten, but when "hairy" caterpillars were placed in the coop they were picked up but immediately dropped. Of six such caterpillars put in the coop at intervals, the first three were treated as above and the last three ignored.

When the chicks were about three weeks old, the scratching that accompanies adult feeding began. While the birds fed from a small metal tray they would stop and scratch with both feet on the wire floor and then eat from the tray again. The scratching was done outside the tray, and although the food particles were not scattered and no new particles were turned up, the impulse was satisfied, and the birds fed as though the scratching were effective.

When the birds were three months old and established in outdoor pens (8′ x 8′) they became excited or "wild" when anyone approached. During these intervals the birds flew about wildly, but often stopped in the midst of their excitement to peck at a choice morsel.

Drinking.—Indiscriminate pecking was also instrumental in teaching the young partridges to drink. Water was given to the birds when they were two days old. The drinking dish was half filled with pebbles to prevent it from being tipped and to keep the chicks from sitting in the water. The pecking birds soon found the water. The first peck caused the bird to shake its head as if to shake free the drops. With the second peck the chick raised its head far back, staggering backward as it did so; some birds even lost their balance and fell. This "peck-and-stagger-back" method of drinking improved rapidly into the normal posture, and within a week a watering tray could be used.

Dusting.—Adult partridges are known to be persistent dusters. Our observations with penned juveniles are interesting in that respect. First, a brood of 15 chicks was kept with an improperly deloused bantam, and all birds contracted lice. The bantam was promptly removed, the birds dusted with an insecticide, and a sand dust bath placed in the brooder. Although the chicks gave every appearance of health and continually walked through the bath and pecked in the sand, it was never used for dusting (age of chicks: 8 days). All the birds died within two weeks.

Another brood that had no lice and had been kept inside on wire for three weeks was placed in an outdoor brooder, the floor of which was covered with an inch layer of sand for sanitation. No sooner did these five birds get into

the brooder than every one began to dust so violently that the dust could be seen coming out of the ventilators. These birds had never seen or felt any sand before.

It appears from these observations that the dusting reaction matures somewhere between the fifteenth and twenty-fifth day, and is probably correlated with the acquisition of juvenal plumage.

It is commonly supposed that partridges dust to rid themselves of ectoparasites. From our observations of penned birds there appears to be another important function of dusting, namely, the "sanding off" of the sheaths on newly developing feathers. Dust and grit lodge between feather sheaths and undoubtedly have a sanding effect as the wing and tail are shuffled in dusting and preening. The grit also appears to aid the bill in the removal of sheaths from the body feathers.

Grit and scaly, dandruff-like remnants of the sheaths are found in the brooder under the night roost of juvenal birds. This indicates that some sheaths are removed during the night and that much of the fine grit dusted into the feathers during the day remains to be preened out in this sheath removal.

Calling.—The call of the adult partridges has been well described by several writers. Although the groupings of letters to illustrate the call differ, each can be adapted by voice to sound something like the partridge. In this study we found six separate vocal sounds given by the partridge. The first call is that of the "chick peep." It can be heard before the chick is hatched, on the twenty-fourth day of incubation, and it is used until the bird is three to four weeks old. The sound appears to be identical with that of the pheasant, quail and domestic chicken at the same age. It is used as a localization and distress call by the chicks.

The second type of call is a "rattle peep." This sound is first made when the bird is about four weeks old. It has the tone of the chick peep, but is an effort to make an adult call. It is the most amusing of all the partridge's vocal efforts. When several four-day old chicks were placed in the same coop with a pair of pen-reared adults, one chick gave the "rattle peep" call six to eight times during a half-hour interval. This would indicate that the call is used in the wild sooner than it is in penned conditions away from adult partridges.

Call three is the "excited" call. It is used by penned birds when a person approaches the pen; in the wild it is used when danger is suspected (observed from a blind). The birds are usually moving when this call is given, and invariably it is accompanied by a flicking of the tail. The call sounds like a muffled "kuta-kut-kut-kut" given rapidly over and over. Heinroth (1928: 3: 238) gives this as "duck-duck-duck."

Closely associated with the excited call is the hiss, used by adult birds during the breeding season and heard when the coop of a mated pair is approached. It is a "haaaah-haaaah" given in a harsh and breathy whisper. The hiss is used by both the female and the male. The birds are active when the sound is made, and no baying or aggressive stance is taken by either bird. The hiss was not heard when the birds were in coveys. Although the nests of wild partridges were often approached, no wild bird was ever heard to hiss. The sound is easily audible at ten feet and cannot be mistaken when once heard. The hiss is occasionally used when mature birds are handled.

The fourth call is that which accompanies feeding and is used by chicks older than five weeks and by adults. It has been heard as given by both wild and penned birds. Heinroth aptly describes the call as "güp güp," the German sound of ü with the umlaut coming closer than any English counterpart.

The "rusty-gate" call is the common crowing of the partridge; it is known to farmers often before the bird is known to them. The call is given in the early morning and in the evening, but it is not uncommon to hear it during the day. The sound is like that of a swinging rusty gate. It is best described as "keee-uck!" with a long, very metallic tone to the first syllable and accent on the second. Occasionally this call is given rapidly along with the "excited" call when the bird is disturbed. Particularly is this true after covey break-up. Whenever an alien cock nears the crowing site of a male, the intruder is driven off as the "rusty-gate" call is given in a low whirring chatter by the pursuer, after which the crowing male gives the call loud and clear.

The "brood" call is the last of the recognized calls and it is used by an adult to signal the brood and to call in strays. We have heard it several times in the wild. One of these instances has been described under *Hatching*. It sounds like a low, purring "burruck-burruck." This call, even when poorly mimicked, brings striking results. It was tested on a group of six-week-old penned birds, where the observer called from a blind adjacent to the pen. In a flash all birds had taken to the cover in the pen and remained quiet for 15 minutes. The mimicking was effective until the birds were nine weeks old, when they slowly began to lose faith in the "warning." As in the incident discussed under *Dusting*, these birds responded to a totally new stimulus, since they had been brooder-raised and had never been near an adult partridge.

There may be variations of these calls, and it is possible that there are still others not here described.

Playing.—A peculiar kind of behavior by our penned birds was observed by accident in the summer of 1943. While trying to box-trap two escaped birds, the following performance was observed from a blind overlooking one of the pens.

Date, October 22; time, 2:30 p.m.; sun bright; day warm and clear; age of birds, 6 weeks; number 6. The coop was 10′ x 10′, the ground cover 15″ June grass, part of which was trampled down, leaving teepee-like bunches still erect. The first motion seen was a series of short runs by one or more birds accompanied by a hop or two, after which the birds ended up in a tilted position with the posterior part of the body raised and the legs extended forward so that the tarsi lay on the ground. The head and shoulders were lowered so that the head was almost between the feet. The tail was continually flicked up and down, and was slightly fanned so that the rust-colored feathers were visible over the bird's back. Often the birds would be feeding when for no apparent reason several birds would hop, run, make a half turn, hop, run, and end up in the tilted position flicking their tails. Then as fast as the commotion started it would stop and the birds would resume their normal behavior. The partridges were forced to remain in a heated brooder until 9:30 each morning, and although the behavior described was seen often at all times of day, it always accompanied the release of the birds from the brooder to the pen. We do not know when this behavior pattern matures, since it was first seen at six

weeks of age. It was observed daily until the birds were eight weeks old, and could be seen occasionally at seventeen weeks. The closest resemblance to this performance is seen during early courtship in February, when the males alone appear to participate. Interestingly enough, these penned birds were all females.

FOOD SELECTION EXPERIMENT

In November of 1941 our nine surviving birds, two males and seven females, were in full post-juvenal plumage and looked like adults. Their diet of wheat and commerical "starter" had not been changed since they were one month old, before which time they were given only the commercial feed.

Beginning in November and throughout the ensuing winter the birds were offered a number of cultivated grains that they had never eaten. The object was to note the choice of grain and the amounts consumed of each. Wheat was kept in the experiment to see how its consumption compared with that of the new grains. The birds were placed in a winter pen 16 by 32 feet with corn-shocks as a weather shelter. To hold the grain a long, partitioned trough was placed on each of the two long sides of the pen (east and west) and protected by a roof from snow and rain. Each of the nine compartments of the trough held a pint of grain without spilling or being easily scratched out. Grit was furnished in the form of clean road gravel, so that the choice of grit size was left entirely to the birds.

The compartments were replenished when they were one-quarter to one-fifth full, never allowing any to be completely emptied. No difficulty was encountered in getting the birds to feed from the troughs, and neither trough was used more frequently by force of habit. The east trough had 107 fillings of grain as compared to 103 on the west side. The grain test ran 106 days, from November 9, 1941 to February 23, 1942.

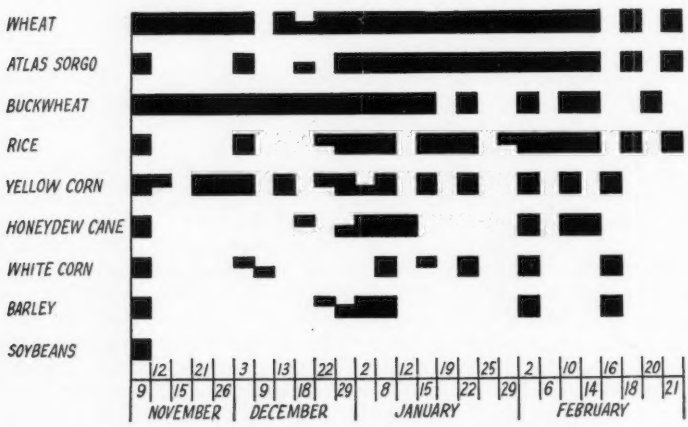

Fig. 28.—Consumption rate and preference table of grains fed to penned Hungarian partridges.

Pilfering by mice and sparrows was anticipated. The mice were kept trapped out, and the sparrows were fed outside the coop.

Grains are listed in Table 14A in order of their preference. Wheat, the grain used during the pre-test period, was preferred. Soybeans were untouched during the experiment despite a change to fresh material in late December.

The temperature dropped and remained below zero from January 1 to January 12 of the test period. It was during this interval that all grains were consumed in larger amounts (except soy beans). Immediately after this sub-zero period buckwheat, a favorite from the start, was consumed at a lesser rate, and atlas sorgo, which had been eaten sparingly, was taken in large amounts. It appeared that these two grains had been switched in the preference rating by the cold wave. This is best illustrated in Figure 28, in which each refilling appears as a black block. The top half of each block means that the east trough compartment was filled on that day, and the bottom half refers to the west trough.

TABLE 14A—Food Selection and Consumption Rate of Penned Hungarian Partridges, 1941.

Grain	Grams Per Pt. Measure	Compartment No.	Consumption, Grams				
			Total	% of Total	Per Day	Per Bird	Per Day Per Bird
Wheat	343	8	15,435	22%	146	1791	16.9
Atlas Sorgo	373	6	13,055	19	123	1543	14.6
Buckwheat	309	4	11,124	16	105	1270	12.0
Rice	277	2	8,310	12	78	982	9.3
Yellow corn	330	3	8,250	12	78	945	8.9
Honeydew cane	372	1	5,208	8	49	610	5.8
White corn	332	7	4,316	6	41	498	4.7
Barley	277	9	3,324	5	31	285	2.7
Soybeans	320	5	0	0	0	0	0
TOTALS			69,022	100	651	7924	74.9

TABLE 14B—Food Selection of Pheasant, Quail, and Hungarian Partridge in the Wild, 1940.

Grain	Total Consumption (Gms.)	Compartment No.
Yellow corn	6325	1
Honeydew cane	3761	2
Atlas Sorgo	3235	7
White corn	3054	3
Buckwheat	2846	6
Soybeans	2396	8
Rice	1615	4
Wheat	1612	5
Barley	830	9

Rice was consumed sparingly until after the cold period, and although not eaten as much as either buckwheat or atlas sorgo, its consumption was much greater than before that time. Yellow corn appeared to be unaffected by temperature changes: its rate of consumption was moderate throughout the experiment. Only during the cold period were honeydew cane and barley eaten in any quantity. White corn had a poor consumption rate throughout and had the poorest showing during the sub-zero weather. Soybeans never went beyond the initial filling.

If a learning process brought about the various irregularities in selection, it was not detected. The place each grain had in the trough (Table 14) also had no bearing on the rate of consumption. Neither was the shape or color of the seed a determining factor in the choice. Atlas sorgo, second in the consumption rating, is round, white and the size of number five shot, while buckwheat, only slightly less preferred, is black, three-sided and twice the size of the sorgo. Neither is comparable to wheat, the control grain, which is light brown and oblong. Furthermore, both sorgos, atlas and honeydew cane, are the same size and shape and belong to the same variety, differing only in color since honeydew cane is brown. Atlas sorgo was second in consumption rating and honeydew cane was sixth.

Hawkins (1937:68) shows that in the wild the Hungarian partridge consumed one pound (454 gms.) per week of various grains, some of which were used here. Converting the "amount per bird per day" column in Table 14A into a weekly total, we get 525 grams. This figure comes close to Hawkins' 454 grams for field feeding.

All the above grains were likewise fed to Hungarian partridges, pheasants, and quail in the wild during the winter of 1940. The feeding troughs were covered with one-inch chicken wire to prevent pilfering by squirrels and rabbits. The nature of the winter limited the use of our "preference troughs" so that the quantity of grain consumed is no indication of the number of birds fed or the length of the experiments. These birds were fed yellow corn in the feeding shelters *before* the test run was made. When the results of the preference of the wild mixed population (Table 14B) are compared with the data in Table 14A, two points are evident; one, that no grain had the same preferential rating in both experiments, and two, that the grain fed before the birds were given supplementary choices was most eaten.

Until the basic principles of food selection in wild birds are understood and the biochemical variations in wild food and physiochemical needs of game birds ascertained, the results of a test such as this can be only presented but not explained.

The Covey

MAKE-UP

From observations made during this study we believe that coveys are formed by single family groups and by a combination of family groups. Where and when unmated birds, if any, join the winter coveys is not known, but by mid-November all winter units are established. During the winter of 1940-41 special effort was made to discover if covey size was flexible or whether the

numbers remained constant. After five months of observation, it was found that no definite rule applied to all coveys. Some held their numbers very well, others fluctuated.

In one instance a group of 14 partridges was continually seen at a feeding site from where they would flush either as two groups of seven or as a single covey. This was also true at another site where a group of 19 would break up into 16 and 3 birds or flush altogether. The problem became one of knowing which group could be called a covey. A few groups added or lost a bird throughout the winter, while some remained intact. Winter mortality accounted for some lost birds, but no attempt was made to measure this loss by individual covey tallies.

Mobility

Winter coveys seem to do little moving if food is close by, and at Faville Grove food is available either as grain residue, shocked corn, manure, weed seeds, or by artificial feeding, so that movement brought about by food shortage was not seen. The average radius of mobility for the winter coveys was one-half mile. Some were confined to cornfields less than a quarter-mile square and could be found there at almost any time. Several coveys were known to move over a mile in the latter part of the winter.

Partridges were watched from a cornshock blind as they fed, and their rate of movement was noted to be surprisingly slow. The birds flew into the cornfield to feed, doing some calling and much tail-flicking after landing, but in three to five minutes all birds were feeding quietly. Their necks were contracted so that from a distance they appeared to be headless. Their movement in the corn stubble was measured in several instances, and it was found to take the birds 16 minutes to move a distance of 12 corn rows, or about four feet per minute. The partridge can run very fast if necessary, however, and on occasion does run for a short distance before the take-off or when crossing an opening or road.

The moving birds spread out over the stubble, the lead going from one bird to another in no orderly procedure, the covey keeping fairly close together. The movement is like that of an amoeba, the birds comparable to the pseudopodia. This slow movement may be a protective adaptation against being seen by raptors, as rapid movement could easily be noticed from above. While moving about the birds often ruffled their feathers as though they were dusting, but the snow was not used as dust.

Some movement of winter coveys and spring pairs was observed and has been described previously, but this does not exclude the possibility that much longer movements may occur. Large-scale banding will be necessary before the year-long picture of mobility is complete. One reason why this has not been done is that partridges are difficult to trap.

Feeding Locations

In the 1941 check on coveys at Faville Grove, the locations of feeding sites were tabulated from the first of November through February. Although

all farmers did not spread manure in the same way or on the same type of field, the following were the sites as seen in 81 observations of coveys feeding.

Corn stubble without manure	31	(without shocks 2, with shocks 29)
Corn stubble with manure	30	(without shocks 7, with shocks 23)
Grain stubble without manure	12	
Grain stubble with manure	8	

Snow covered the ground at the time when most of the observations were made.

ROOSTING

In some instances the birds observed were not feeding, but were either loafing or "day roosting." Thirty such resting sites were seen, half of them on flat ground and half on a slope. South slopes were most used, west slopes least.

Night roosting was done in various locations and in several different ways. Roosting was noted on barren hill, in fencerow, ragweed tangle, base of shocked corn, straw stack, center of a gravel road, wheel rut on a snow-covered road, and others. Hungarian partridges are said to jug like quail, which is often the case, but in numerous instances the partridges were spread out over an area twenty feet in diameter. The heads of the birds, as indicated by the position of the droppings in night roost "forms," were not pointed in any particular direction.

The number of droppings varied from 12 to 81 per bird per night at any one roost. Figure 29 shows 408 droppings (100% green vegetable matter) of five birds, plus 5 caecal droppings, 3 of which can be seen in the photograph. The type of food and length of stay at any roost may determine the dropping

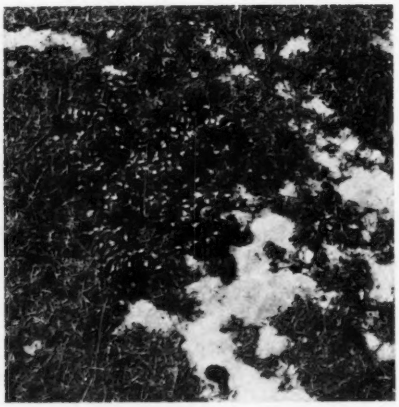

Fig. 29.—Droppings at a Hungarian partridge roost; three caecal droppings show overnight occupancy.

count, but the "mounds" together with the caecal droppings give a fairly good index to the number of birds roosting. Both day and night roosts of the male during the incubation period were found, seldom more than 25 yards distant from the nest. During a check on flight distances a single covey was reflushed several times, and the forms at the spot of landing sometimes contained one or two complete droppings. The birds were never in those forms more than five minutes during this flight check.

FLIGHT

The most frequent winter flight distance of partridge coveys, measured by pacing from flushing point to landing point, was 300 feet. The longest and shortest distances in natural flight were 1200 and 100 feet respectively. The method of flight is a series of rapid wing strokes followed by a glide, both repeated until the landing point is reached. The lead in flight changes because not all birds glide at the same time, hence counting birds in flight may be quite difficult. If a covey count is desired, it is best to approach from a higher point, or to flush the birds in a direction where clear vision is assured. Brood flight distances vary with age (Yeatter 1934: 42). After covey break-up, pairs were observed to fly much shorter distances than coveys had flown, the most frequent distance being 150 feet. Coveys hook to the right or left when about to land, but are best "marked" when they flutter their wings and rise slightly before alighting.

DISPLAY

The Hungarian partridge is both shy and wary to a degree which makes it hard to detect any attempt at display. There are only three colorful spots on its body: (1) a reddish copper-colored tail (rectrices); (2) a cinnamon-colored, horseshoe-shaped feathering on its gray breast; and (3) a bright vermillion-colored featherless area around the eye that reaches a peak in color just before the breeding season.

Tail flicking is the most frequently used display. It is used by birds that are uneasy or fearful. The birds react to a disturbance by either squatting or by becoming erect, in which case the squatting birds can easily see the signalling of the rapid tail flicking of the erect birds. When the disturbance becomes great enough the standing birds take off, showing in a flash the entire red tail in flight; all birds react immediately and the covey is in the air.

In courtship, as explained earlier, the male fluffs himself up a little and extends his wings along his sides as he pursues the female. In ten hours of observation of this behavior in the field, the use of the red tail or cinammon horseshoe as part of courtship was not discerned. Any function of the vermillion eye patches could not be determined.

A threat display of the Hungarian partridge was noted with pen-reared birds but not in the wild. The incubating hens in several coops spread their wings well over the nest, hissing loudly, and the males also hissed, but in no instance did the birds become aggressive.

TOLERANCE OF HUMANS

The Hungarian partridge, as previously mentioned, is noted for its tolerance during the late stages of incubation. Early in this study Hawkins examined a nest with 21 eggs found by a road crew. The crew flushed the hen from her nest repeatedly; a road scraper dug the road eight inches deeper just one foot from the nest; a debrushing crew cut away most of the nesting cover over and around the nest; a farmer mowed, raked and loaded his hay five feet from the nest, all during the two-week period the nest was under observation. Yet the partridge hatched 19 of the 21 eggs.

Another instance of tolerance was noted when a pair of partridges nested in the city of Lake Mills. The nest was located just 12 yards from a sidewalk in a half-acre field of timothy behind a garage. Many similar cases have been recorded by others.

Partridges appear to be quite tame when driven by hunger to farm buildings or when feeding in fields recently spread with manure. A team of horses may get very close to the partridges in the field, but it is difficult to approach a covey on foot at any time. In spite of the partridge's occasional tolerance, it is a wilder bird than either the pheasant or bob-white. Penned partridges almost never reach the state of semi-domestication often attained by pheasants and quail.

Appraisal

At the outset of this study we aimed to manage the Faville Grove partridge population, and we thought that the partridge density would be raised by the management. Today, after eight years, we have not yet succeeded in raising or even maintaining the densities present at the beginning of the study. Our study in its course was broadened to include ecological exploration of the Wisconsin partridge environment.

The management practices were confined to winter, and although they failed in their ultimate objective we found that:

(1) Partridges seldom feed from a hopper or permanent shelter but can be fed successfully from a teepee cornshock shelter placed in an open field. These feeders are best placed in fields of corn stubble with the open side to the south.

(2) Spreading of manure and spoiled ensilage instead of storing it in the barnyard is a good way to feed Huns in winter.

(3) The raptor problem is a local one, and at Faville Grove no control was necessary.

According to Leopold (1932: 32) management depends upon "spotting" and controlling the limiting factor. Although we do not know what the limiting factor is, our censuses, nesting and climograph studies "spot" summer as the season when it is operative. Nesting loss and non-breeding are two possible reasons for the low rate of summer gain. There is nothing the farmer or game manager can do at present about changing the phenology of haying or about non-breeding. We can suggest several untried practices that might minimize nesting loss.

(1) Leave undisturbed all possible plant growths of the previous year that might be used for early nestings. This can be accomplished by refraining from spring burning of roadsides and fencerows. Burning may force potential nesters to build in hayfields where mowing is likely to cause failure.

(2) Plant strips of nesting cover. These strips need not be more than one rod wide and should be placed along fencerows and between field crops. To insure safe hatching the strips should not be mowed until the end of July. The hay might be utilized as over-mature hay, as a seed crop, or as late summer pasture.

(3) Rigidly control stray cats and dogs to protect incubating birds. While the merits and shortcomings of the flushing bar are obvious, we do not either advocate or discourage its use.

Many ecological investigations have been made purely on the basis of factor analysis. This method we too have used, not however without the realization that our efforts were only half rewarded. It is clear, perhaps not in whole numbers or percentages, that the other half of the answer lies in the study of population behavior, turnover, sex and age classes within and between populations, the comparisons of various groups of birds (e.g. Gallinae as a group), and the behavior of geographically separate populations of one or more species.

At the termination of almost every piece of ecological research there remain certain questions either unanswered or about which we need more information. We have therefore listed below a number of such questions which we believe worthy of further study. This list does not imply that these are the only questions, or that the points covered in this paper are in any way final.

QUESTION	APPROACH
1. What is the turnover rate?	5-10 year banding program plus bursal probing, censuses.
2. What is the sex ratio in coveys?	5-10 year banding program, hunters' bag tally.
3. What is the age ratio in coveys?	5-10 year banding program plus bursal probing, hunters' bag tally.
4. What is the extent and nature of spring and fall movements?	5-10 year banding program.
5. Is the wintering ground and nesting ground the same?	5-10-year banding program plus field observations.
6. What are population characteristics of thrifty and low densities?	Comparison of banding data from areas of high and low densities (Canada and Wisconsin), annual censuses.
7. To what extent does the partridge display? a. function and use of color. b. importance in mating.	Spring observations: spotting scope, blind, field glasses.
8. To what extent is the partridge territorial?	Spring observations: spotting scope, blind, field glasses.
9. What diseases and parasites affect the Hungarian partridge?	Examination of collected specimens used for food habits. Hunters' bags.

Summary

The Hungarian partridge was introduced into Wisconsin and Alberta in 1908. In thirty years the Canadian introduction has spread over much of central Canada and the densities are high, while Wisconsin has low densities

with only the south-east quarter of the state populated. These low densities are reflected in state hunting returns and in the censuses of a non-hunted area (Faville Grove).

Partridges extended their range since the initial release in Waukesha County in 1910 to an area covering all or parts of 19 southeastern counties.

The partridge ranges of North America were climographically compared with the European range and it was found that (1) the north central states are too warm in the breeding and brood season and (2) that low temperatures do not affect partridge survival.

Prenesting activity of Wisconsin partridges differed little from what has already been described in the literature.

After the formation of pairs, nesting sites are chosen in cover at least eight inches high. The average clutch laid is seventeen eggs; the incubation period is twenty-five days. During incubation 574 egg weights showed a loss of 15% at hatching. In six years the hatchability varied from 74% to 93%, with an average of 85%. Sixty-eight per cent of the 435 nests failed to produce young. Of the 68%, hay mowing caused 77% of the failure, predation 10%, and cutting weeds with a scythe 6%.

In our most successful years of nest finding we were able to account for only one-quarter of the possible breeding pairs. This appeared to be an accurate nest census. What became of the remaining birds is not known.

In computing the history of deserted nests, our inability to estimate age of unhatched embryos introduced a sizeable error. To eliminate this error a key to the age of embryos was worked out. A key to the age characters of chicks through thirteen weeks was also made. Nest phenology computed with the help of information gathered during this study showed that hay mowing coincided with the peak of hatching during each of six years. This fact made hay mowing one of the probable reasons for low partridge densities in Wisconsin.

A series of dummy nests to check possible egg predators revealed that: (1) Franklin ground squirrel, 13-lined ground squirrel, skunk and crow ate partridge eggs; (2) The evidence concerning woodchuck, fox squirrel and badger was inconclusive.

The weight growth of several groups of pen-reared chicks was recorded and the best sample showed that their ultimate weights were the same as that of wild birds. The growth may have been retarded about ten days, however.

A secondary sex ratio of 331 embryos showed a dominance of females (57%), but a tertiary sex ratio of 115 adults showed a dominance of males (58%).

The sex of embryo partridges was determined as early as 7 days by sectioning through the gonadal region and examining the slides under a microscope.

The pterylography of the partridge was worked out from embryos, dead chicks and hunting kill adults.

In a behavior study of penned chicks, it was found that feeding and drinking are "learned" by the second day through a random pecking process. Dusting is not indulged in until the birds are two weeks old. Chicks react to call as soon as they are hatched. At six weeks the chicks were observed playing

by running, dipping and bouncing at each other—similar in a sense to the antics used in courtship.

A food-selection experiment with a group of nine adult birds showed a preference for the grain they were raised on, even when given a choice of eight other grains. They suddenly shifted their second and third preferences during an extremely cold period.

Partridges are tolerant of humans only under stress of hunger or while protecting the nest or young.

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Age, Growth, and Habits of the Hog Sucker, Hypentelium nigricans (LeSueur), in New York

Edward C. Raney and Ernest A. Lachner

The hog sucker, *Hypentelium nigricans* (LeSueur), is a well known fish of the riffles and adjacent areas of warm, clear, shallow streams with rubble bottom. Its extensive range includes Minnesota and Lake of the Woods, the entire upper Mississippi River system, eastward to southern Ontario and New York; south to Georgia in the East, the Gulf slope of Mississippi, southwestern Arkansas, and eastern Oklahoma (Hubbs and Lagler, 1941: 42). Although it is sometimes caught by fishermen in the spring on hook and line, it is not often eaten because of its small average size and the presence of many small bones. It is also called hammerhead, hog molly, hog mullet, crawl-a-bottom, stone lugger, and stone toter.

The bulk of its diet consists of insect larvae, crustaceans, diatoms and other minute forms of vegetation. When feeding it scrapes off the upper surface of rubble, turns over stones on the bottom, and sucks up the ooze, which includes a host of small organisms. Reighard (1920: 21) and Greeley (1935: 92) both report an interesting relationship between the feeding hog sucker and other fishes such as shiners, *Notropis*, and nothern smallmouth bass, *Micropterus d. dolomieu*. These fishes take a position downstream and feed on the aquatic insects and other forms dislodged as the hog sucker turns over rocks. As every boy who frequents small streams knows, hog suckers may easily be caught on worms or snared with a loop or hook as they lie quietly in shallow water. It is most commonly found in warm streams where it is generally associated with the northern smallmouth bass, in whose stomach it has been found. Large hog suckers are sometimes used as bait for muskellunge, northern pike and other large game fishes. It is occasionally found in lakes, usually near the mouths of streams, and apparently thrives in this habitat for the few that we have aged have grown much faster than stream specimens.

It is not primarily a gregarious species. Usually it may be seen lying on the bottom where the black saddles that cross the back act as disruptive coloration and make it difficult to observe. When disturbed it darts off quickly and may swim very fast for a relatively short distance.

A fine colored illustration of the hog sucker is reproduced in Forbes and Richardson (1909: 86) and a female three and one-half years old is portrayed in Greeley (1935, plate 2).

Reproduction

Sexual dimorphism has been studied in some detail by Rheighard (1920: 21). Both sexes possess pearl organs. In the male they cover both surfaces of

all the fins, the top of the head, opercle, and body scales. Those of the female are somewhat smaller and are lacking on the head, sides of body, dorsal fin, and the lower surface of the paired fins. The tubercles on the anal fin are probably most effective in the spawning act. The anal fin is longer in the male. Both sexes are colored alike and do not undergo the change at breeding time that occurs in the common white sucker, *Catostomus, c. commersonnii.* In water during the breeding season the sexes are best distinguished by their behavior, the males being more active and aggressive.

Spawning usually occurs in shallow water of riffles mostly during May in the latitude of New York. Ripe males have been collected as early as April 19 when the water temperature was 60° F. They are somewhat sluggish and generally inactive in water below 50° F. In water as low as 41° F. they are extremely sluggish and have been seen lying quietly along the side of a log or stone in a riffle without moving for fairly long periods. The females are usually found in the riffles only when ready to shed the eggs, and at other times frequent the nearby pools. Several accounts of what was probably breeding behavior have been reported by Reighard (1920: 22) and Hankinson (1919: 136). Behavior similar to that noted by the former was seen by the senior writer in the outlet of Spencer Lake near Spencer, New York on May 6 when the water was 68° F. Several adult hog suckers were seen feeding in a riffle. A large female swam slowly up stream and came to rest on an area of fine gravel. A small male laid along side her and attempted to vibrate. Two other males joined the pair, but the female apparently was not quite ready and swam away after a half minute.

Although the hog sucker apparently prefers to breed in riffles, they sometimes spawn near the shallow sides of pools in the Ithaca, New York region. A parallel situation has ben observed and reported for the common white sucker by Raney (1943: 256). On May 27, 1938, Dr. W. J. Hamilton, Jr., Cornell University, observed hog suckers spawning in shallow water near the down stream end of a pool in lower Newfield Creek, a tributary of Cayuga Inlet about 4 miles south of Ithaca, New York. He has kindly given us permission to record his pertinent observations. The pool, just below an impassable falls, harbored some 35 to 40 hog suckers which varied in length from 6 to 12 inches. They tended to gather in groups of 3, 5, 7 and 12 fishes, each group with a single female, and swam about the pool, the males attempting to crowd about the female. The female when ready to spawn would take a position over the bottom in a restricted area of sand and gravel about three feet in diameter where the water was about 3 to 5 inches deep. The males, usually two or three in numbers, followed immediately and caused a great commotion as they attempted to pack in about the female, their tails and caudal peduncles crowded against her sides. As she extruded the eggs the males became greatly excited and often stood on their heads with the threshing tails protruding from the surface and beating the water into foam. The breeding act lasted approximately two seconds and is repeated after a short period of rest of 4 to 7 minutes during which the female retires to the deeper water but is still followed by her retinue of males. It was noted that a small 6 inch male was one of the most successful of all those present and did not once

leave the side of a female during a period of several hours. As the eggs were laid many minnows, eastern blacknose dace (*Rhinichthys a. atratulus*), and northern creek chub. (*Semotilus a. atromaculatus*), rushed in to feast upon them. The hog suckers showed no interest in food at this time even though an earthworm was dangled in front of their mouths. They showed little concern over the presence of an observer standing only a few feet away and returned repeatedly to the spawning site.

Eggs were recovered from the spawning site the next day when breeding was finished and the hog suckers had departed downstream. Except for one group of four, the eggs were single and were easily obtained by slightly disturbing the bottom and drawing a fine wire screen through the roiled water.

Age and Growth

The study of age and growth is based on an analysis of the scales of 337 hog suckers taken mostly from two localities. During the period from August 11-16, 1940, 181 specimens of hog suckers of various sizes were obtained from the Genesee River, about 4 miles south of Wellsville, Allegany Co., New York. At this time a Biological Survey party of the New York State Conservation Department was engaged primarily in salvaging bass from these waters by the use of the electrical method (see Haskell 1940: 210) and by seining with a 100 foot bag seine. The senior writer was given every opportunity to collect hog suckers as well as other fishes, and wishes to acknowledge this assistance and permission to use this material in the present study.

The Genesee River at the point where the collections were made varies in width from 25 to 75 feet. The water is usually clear and white and flows over a bottom of rubble and gravel, with some sand and silt in pools that alternate with moderate riffles. Few pools were more than four or five feet deep while the riffles were shallow and seldom exceeded one foot in depth. Suitable areas, approximately 100 yards long, were blocked off with seines, and the screen electrode was moved through the area by means of long wooden handles fastened to each end. As the fishes approached the screen they were stunned momentarily, usually floated to the surface, and were easily captured by means of a small dip net. An effort was made to collect and save all large and medium sized fishes, but some specimens quickly recovered from the shock and escaped. Because of limited time and assistance many small juveniles passed downstream unnoticed. Few specimens were obtained by seining in pools, even when known by observation to be present, apparently because the hog suckers hug the bottom near rocks and escape as the lead line of the seine brushes over them. It is believed that this collection is a representative sample of the hog sucker population, and, since there were 86 males and 92 females, it appeares that the normal sex ratio is about 1:1.

The common white sucker and the golden redhorse, *Moxostoma erythrurum* (Rafinesque), were also taken at this locality. The white suckers were about as abundant as hog suckers while redhorse were much less common. Evidence of ecological selection was noted. The redhorse were limited to the

deeper pools and were definitely gregarious, being found in small compact schools of 5 to 8 individuals. At one time the river was quite turbid after a sudden rain storm yet the redhorse were still taken in the deeper pools and in one instance five large specimens were taken within a few seconds. The hog suckers of all ages were most common in the riffles and shallower portions of the pools. The white suckers seemed to prefer the shallower portions of pools. All three species resort to the riffles for spawning during the spring and occasionally also feed there, but otherwise the differences in habitat preference noted above appear to hold elsewhere in New York and Pennsylvania.

Most of the other specimens utilized for the study of age and growth were obtained from the upper Susquehanna drainage in Catatonk Creek and tributaries in the vicinity of Candor and Spencer, Tioga Co., New York. Some 154 hog suckers collected over the period from 1928 to 1939 now in the Cornell University collection were aged and studied. In addition other specimens were used from several other localities mentioned below.

Those collected in Catatonk Creek include a number of specimens of young of the year taken at periods throughout the summer. The validity of the scale method of determining the age of this species was determined by a study of the scales of these known young as well as of the specimens of the same size taken the following spring.

The annulus is usually formed during the first two weeks in May when the mean water temperature at midday has reached approximately 56°-60° F. In one collection taken April 19, 1939 the annulus was formed at the extreme edge of the scale in two specimens two years old, while it was not yet formed in three specimens three years old. Hog suckers taken during the first week in May typically had about half the scales with an annulus at the edge. By the middle of May the annulus is formed on all but a very few aberrant individuals, and all those taken after May 20 had the annulus formed. There appears to be a trend toward an earlier formation of annulus in one and two year old specimens but this suggestion needs to be confirmed by the study of additional specimens.

The annulus cuts across some of the circuli laid down on the posterior lateral field during the previous summer and fall. The first 3 to 5 circuli that form in the spring, when growth resumes, are far apart and more irregular or wavy in character than those of the late summer and fall. Some of these circuli formed in the spring are incomplete especially in the lateral field and anterior fields. The first annulus is at times difficult to find, but can be located by a combination of the annulus cutting across one or more circuli and the fact that the fall circuli are close together, making a dark band as contrasted to a light band formed during the late spring and summer. The first annulus is often best seen in the anterior field. The characters mentioned above may be better understood by a study of the photographs of scales from various aged hog suckers reproduced in Figures 1, 2 and 3. The scales were placed in water in watch glasses and studied under a binocular microscope. No back calculations of growth were made.

The data on age and growth are summarized in Tables 1 and 2 and presented in graphic form in Figure 4. The hog suckers from Catatonk Creek may grow faster than those from the Genesee River, but the difference is probably slight. The data from the two localities are not strictly comparable since those specimens from Catatonk Creek are at least one and one-half months older. The growth is most rapid during the first five years (Figure 2). A decrease in the growth rate occurs during the sixth summer. At this time also a slight difference in the rate of growth of the sexes is noted, the females growing faster. This trend becomes more pronounced during succeeding summers. There is a marked similarity between the growth of the hog sucker and that of the common white sucker in Muskellunge Lake, Vilas Co., Wisconsin as reported by Spoor (1938: 481). However, in comparison with white suckers from Skaneateles Lake Inlet, New York studied by Raney and Webster (1942: 145) the hog suckers have a much slower growth rate and do not

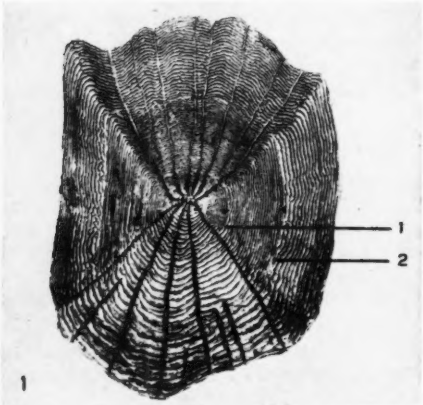

Fig. 1. Scale of a male hog sucker, *Hypentelium nigricans*, 198 mm. total length, from Catatonk Creek at Candor, Tioga Co., New York, on May 14, 1939. It has just completed its third winter but the third annulus is not yet formed on the scale edge. This scale is somewhat more pointed on the posterior border than normal.

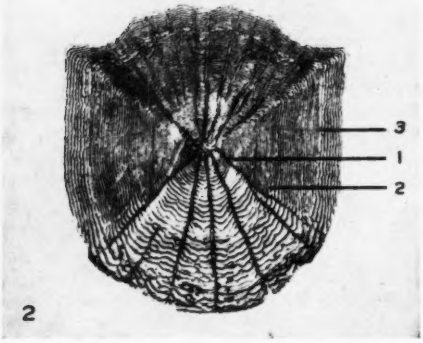

Fig. 2. Scale of a male hog sucker, *Hypentelium nigricans*, 214 mm. total length, collected in Catatonk Creek, 1 mile south of Candor, Tioga Co., New York, on June 11, 1939.

reach as great a total length. The white suckers from the Finger Lakes of Central New York, however, reach an unusually large size.

Five Genesee River specimens reached an age of 9 years and one large female, 350 mm. long, was 11 years old. The largest specimen examined was a female, 365 mm. (14.4 inches) in total length, weight 22 ounces, collected in Cayuga Lake, near Flat Rock, New York by Dr. Dwight A. Webster on

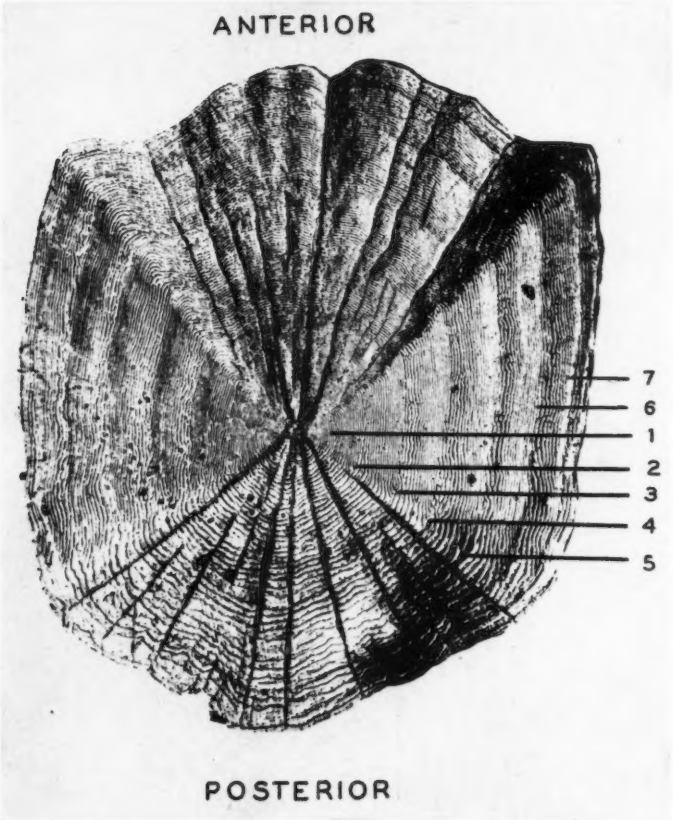

Fig. 3. Scale of a female hog sucker, *Hypentelium nigricans*, 318 mm. total length, from Genesee River, 4 miles south of Wellsville, Allegany Co., New York on August 12, 1940. It is in its eighth summer. Note the annuli cutting across some previously formed circuli on the posterior lateral field of the scale. Also prominent is the banding effect caused by the wide spaced wavy circuli formed during the summer as contrasted with the closely placed rather straight circuli of the fall.

TABLE 1.—Summary of data on age of a sample of 181 specimens of *Hypentelium nigricans* collected in the Genesee River, 4 miles south of Wellsville, Allegany County, New York, on August 12-16, 1940. The one-year specimens labeled as not sexed could not be determined readily with the high power of a binocular microscope.

Age in Summers	I	II		III		IV		V		VI		VII		VIII		IX		XI
	Not sexed	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♀
No. specimens	3	12	11	21	14	11	5	22	36	6	7	7	14	5	2	3	2	1
Range, total length in mm.	42–46	86–122	85–105	114–182	103–163	160–224	151–220	206–291	195–275	230–267	213–296	249–275	232–315	255–292	318–320	274–322	302–346	350
Mean in mm.	44	103	97	144	137	189	187	234	240	244	257	267	280	273	319	290	324	350
Mean in inches	1.7	4.1	3.8	5.7	5.4	7.4	7.4	9.2	9.4	9.6	10.1	10.5	11.0	10.7	12.6	11.4	12.8	13.8
Standard error in mm.	–	9.5	6.3	13.7	18.6	15.5	–	21.3	20.1	–	–	–	19.9	–	–	–	–	–

TABLE 2.—Length frequencies for each age group of 119 specimens of *Hypentelium nigricans* collected in Catatonk Creek and tributaries in the area between Candor and Spencer, Tioga County, New York, from late September to May, 1928-1939. A seven-year-old male, 295 mm. in total length taken in this area, is not included in the table.

Age in Years	I			I+*		II		III		IV	
Total Length cm.	Not sexed	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	5										
5	2	3									
6	8	3	3								
7	2	1	3	1	1	1					
8		2		1	4						
9				5	2	2	1				
10				2	3	2	3				
11					1	4	3		1		
12						2	4		1		
13						7	1	2			
14						4					
15											
16								2			
17								7	2		
18								4	1	3	1
19								5	3	3	
20								3			2
21								5	1		
22										1	
23										1	1
24										1	
25										2	1
No. specimens	17	9	6	9	11	22	12	28	9	11	5
Mean in mm.	58	77	70	105	93	124	115	180	173	214	214
Mean in in.	2.3	2.6	2.8	4.1	3.7	4.9	4.5	7.1	6.8	8.4	8.4

* These specimens were taken on July 4, 1939.

August 21, 1945. This hog sucker was only in its sixth summer. Another female 330 mm. long from Goodyear Lake, Otsego, Co., New York was in its seventh summer. These lake hog suckers have grown much faster than those of the same year group in streams. This is also true of the common white sucker although this species is quite common in lakes while the hog sucker is seldom found there. Goode (1888: 436) claims, and has been copied by many other writers, that the hog sucker "reaches a length of about two feet." Kuhne (1939: 41) reports having seen specimens weighing two pounds. Precise measurements on additional large specimens are desirable.

Some of the larger males mature and breed when only two years old and are about 5.3 inches long, and practically all males are mature when three years

old and 7.1 in. long. On the other hand most females mature at three years when they average 6.7 inches in total length. Some of the slower growing females do not spawn until they are four years old and 8.4 in. long. These data are based entirely upon specimens taken in Catatonk Creek, New York.

We wish to acknowledge the assistance of Robert D. Ross in measuring and sexing the large series from the Genesee River.

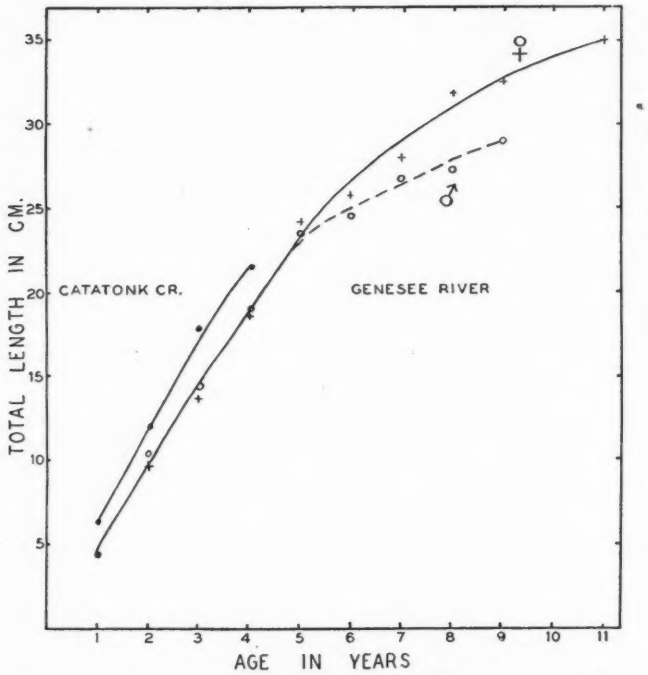

Fig. 4. Growth curves of *Hypentelium nigricans*. The upper growth curve is based on a sample of 119 specimens (70 males, 32 females, and 17 immature specimens which we were not able to sex) collected in Catatonk Creek and tributaries in the area between Candor and Spencer, Tioga Co., New York, from late September to May, 1928 to 1939 (see Table 2). The lower curve is based on a sample of 181 specimens (86 males, 92 females, and 3 not sexed) collected in the Genesee River, 4 miles south of Wellsville, Allegany Co., New York, on August 12-16, 1940 (see Table 1). It is obvious that these hog suckers lacked about one and one-half months growing season in the latter part of the summer which accounts in part for the differences in the growth curves.

Summary

1. Reproduction in the hog sucker occurs in May in New York. Spawning behavior is described.

2. Age and growth were based on studies of scales of 337 specimens from Catatonk Creek, in the upper Susquehanna River system, Tioga Co., New York and from the Genesee River, Allegany Co., New York.

3. In the Genesee River where a representative sample of the hog sucker population was obtained by an electrical method, 86 males and 92 females were taken indicating a probable sex ratio about 1:1.

4. Ecological niches occupied by the three species of sucker found together in the Genesee River were noted. The hog sucker was found in the riffles and nearby shallow portions of pools; the common white sucker, *Catostomus c. commersonnii,* was most common in the shallow pools; the golden redhorse, *Moxostoma erythrurum,* was gregarious and the adult was found only in the deeper pools. All three resort to riffles in the spring for spawning.

5. The scale annulus is usually formed during the first two weeks in May when the mean water temperature is 56°-60°F.

6. The annulus is best seen on the posterior lateral field of the scale as it "cuts across" some of the circuli formed previously. Banding is also pronounced, caused by the relatively large distance between circuli formed during the late spring and summer as contrasted to those laid down close together later in the season.

7. Both sexes grow rapidly and at about the same rate for the first five years. Thereafter the growth increment decreases considerably and more so in males than females.

8. Hog suckers from Catatonk Creek attained a total mean length of 2.5, 4.7, 7.0, and 8.4 inches at the end of their first, second, third, and fourth years.

9. In the Genesee River the length at the end of the first year was 1.7. Males reached 4.1, 5.7, 7.4, 9.2, 9.6, 10.5, 10.7 and 11.4 inches at an age of two to nine years. Females attained 3.8, 5.4, 7.4, 9.4, 10.1, 11.0, 12.6, 12.8 inches at the same time. The oldest specimen examined was an eleven year old female.

10. The largest hog sucker examined was in its sixth summer, 14.4 inches total length, weight 22 ounces ,and was collected in Cayuga Lake, New York.

11. Some males mature for the first time at two years, practically all at three. Most females mature at three years, the remainder at four.

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An Annotated Bibliography of Papers Relating to the Control of Mosquitoes by the Use of Fish

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Man's interest in the control of mosquitoes has increased greatly during the second world war. In large measure this is due to his numerous contacts with them in tropical areas. Various control measures have been tried. Of these probably the most permanent and cheapest mosquito control method is the use of fish. The natural habits of both fish and mosquito larvae must be taken into consideration in selecting a species of fish to be used for the destruction of larvae. The problem of attacking the varied species of Anopheles is complex. They are commonly found in pools containing much vegetation and may be almost completely hidden by the surroundings. Keeping in mind the habits of the larvae the fish used must be a species that will search for food not only in the shallow water but amid dense vegetation.

In pools, ponds, swamps and other natural bodies of water an adequate supply of food and the breeding habits of the fish become very important points for consideration. For satisfactory control the fish used must breed rapidly in order that large numbers of them will be present at all times when larvae are apt to occur. Carnivorous fish are preferred to omnivorous feeders. Surface feeders are considered to be most satisfactory, although sun-perch and goldfish under some conditions may be effective. Indigenous fish as a rule are easier to maintain than imported fish.

Dr. S. F. Hildebrand[1] states that many of the species used in containers at one time or another are utterly worthless in open bodies of water. Virtually any hardy sluggish fish is suitable for mosquito control in containers. In fact, herbivorous species are used with success in barrels and cisterns because they generally are sluggish and will not jump out of the containers. Little or no plant food being available, the vegetarians will feed on wiggle tails. The problem is altogether different in nature, for there any useful species must normally by choice feed on mosquito larvae.

All available literature dealing with this subject published since Howard, Dyar and Knab's "The Mosquitoes of North and Central America and the West Indies" up to and including 1942 has been reviewed. The comments given under the references are observations of the respective authors in connection with fish as a controlling factor. Two hundred and ninety-eight articles are listed. A summary of the facts presented reveals that two hundred and sixteen species of fish have been used in the control of thirty-five species of mosquitoes in forty-one countries. The chief publications used as sources for titles are: "Review of Applied Entomology, Series B," and "The Use of Fish for Mosquito Control" (Rockefeller Foundation, 1924).

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1 S. F. Hildebrand, Fish and Wildlife Service, U. S. National Museum.

1*. ADERS, W. W. 1913—Entomology in relation to Public Health and Medicine. Zanzibar Protectorate Med. and Sanit. Rept. for 1913: pp. 76-82. The following fish were reported to be larvicidal in India: *Polyacanthus* sp., *Mugil* sp., *Ambassis commersonii*, *Ophiocephalus striatus*, *Danio cyprinides*, *Cirhina latia*, and *Barbus terio*.

2.* AITKEN, E. H. 1901—Notes on Anopheles or Malaria Mosquito. Jour. Bombay Nat. Hist. Soc. **13**:695. Of all larvicidals, the most effectual, in the case of Anopheles, is the little fish. The author has never found larvae and fishes in the same pool. Aitkens advocated two species as particularly useful, one the indigenous "Piku" fish (*Panchax lineatus*) and the other the exotic goldfish (*Carassius auratus*).

3.* ALCOCK, A. 1902—A Naturalist in Indian Seas. 201 pp. London. Alcock observed at Aueutta Island in the Laccadive Sea that the wells and tanks positively swarmed with a little species of carp (Barbus), and with two species of sea-fishes acclimatized to fresh-water. As a result no mosquitoes were found on this island, while they were in abundance in the adjacent islands of Minnikoy where in the wells and tanks these fishes were almost absent.

4.* ALCOCK, A. 1920—Entomology for Medical Officers. 2nd Edition. pp. 70-72. London. In his first edition the author referred to the well-established laws of nature, and in considering the "Nature Enemies" of mosquito larvae suggested the use of small fishes of the family Cyprinodonidae as larvivorous forms. In the second edition of this work fishes were placed first among the natural enmeies of mosquito larvae with the remark particularly those that frequent the surface, and especially Cyprinodonidae, which are found all around the globe in low latitudes and can live in water of any quality and temperature. Although natural enmeies have their application in these and similar circumstances, they are a minor consideration of rural sanitary policy.

5.* AMBIALET, R. 1937—Observations sur la campagne antipaludique de 1936 et sur les campagnes anterieures dans de departement de Constantine. Arch. Inst. Pasteur Alger. **15**(3):389-410, 3 pls., 12 graphs. A discussion of the use of Gambusia in Algiers against anopheline larvae. Relating some of the reasons why they did not give satisfactory results, with suggestions for means by which their rearing and distribution might be more satisfactorily carried out.

6. ANTI-MALARIA ASSOCIATION. 1913—Mosquitoes and "Millions." Agri. Jour., Union of South Africa, Pretoria, **6**(5):829. The Anti-Malaria Association was instrumental in importing a consignment of the West Indian fish, known as "Millions," with a view to acclimatising them in South Africa. The fish consigned to the Stellenbosch Hatcheries have made excellent progress.

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8.* ARTOM, C. 1924—La specie di Gambusia acclimatata in Italia (*Gambusia holbrooki*) in relazione colla stabilita del carattere del gonopodia. (The Species of Gambusia Acclimatised in Italy (*Gambusia holbrooki*) in Relation to the Stability of the Character of the Gonopod). Atti R. Accad. Naz. Lincei, Rend. Classe sci. fis., mat. e nat., **33**(7-8):278-282. In the United States the mosquito-destroying fishes of the genus Gambusia are distributed as follows: *G. holbrooki*, in a zone between the States of Virginia and Alabama; *G. patruelis* from the State of Florida to the State of Texas; and *G. affinis* from Florida to Tampico, Mexico. The species imported into Spain and Italy, and now established there, is *G. holbrooki*. The development of this species in Italy is more rapid than in the United States.

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12. BAHR, P. H. 1912—Investigations in India and Malaya upon Malaria. Tropical Diseases Bulletin **1**:117-118. A carefully prepared scientific study of some fifteen to twenty varieties of larva-eating fish have been discovered and studied as to their fitness for use in tanks, ponds and rice-fields.

13. BAHR, P. H. 1913—Malaria in Kurunegala, report dated Ceylon, April 1913, forwarded from the Colonial Office. 8 pp., 11 photos, 1 map. Summarized in Tropical Diseases Bull. **2**:535-538. Pertaining to the same study as in reference (12).

14. BALFOUR, A. 1925—Report on Medical and Sanitary Matters in Bermuda, 1923. Fol., 91 pp., 107 figs., 1 map, 1 chart, 1 plan, London. Crown Agents for the Colonies. The methods hitherto adopted are those usual in Anti-mosquito work, the use of fish being particularly successful. Gold-fish have proved of great value in tanks, barrels, etc., but will not survive in cisterns exposed to the summer sun, the temperature of which may rise to 100° F. In such cases an indigenous fish, *Fundulus bermudae*, is used. This readily devours mosquito larvae, but as it also feeds on vegetable matter, cisterns must be kept free from algae.

15.* BALFOUR, M. C. 1936—Some Features of Malaria in Greece and Experience in its Control. Riv. Malariol. **15**(2):114-131, 6 refs. Gambusia was introduced into Greece from Italy in 1928 and a special field study of its action was conducted in the Plain of Lamis. The author stated that it was doubtful whether the fish could control the larvae of *Anopheles superpictus* in torrents subjected to floods. No information has been seen as to the effectiveness of the control measure.

16. BALLOW, H. A. 1908—Millions and mosquitoes. Barbados. Imperial Dept. of Agriculture for the West Indies. Pamphlet ser. **55**: 16 pp. Use of the "millions" fish in Panama did not result in its establishment.

17. BANNERMAN, W. B. 1910—Note on Dr. Bentley's Paper, "The Natural History of Malaria." Jour. Bombay Nat. Hist. Soc. **20**:525. The author confirmed Bentley's observations regarding the efficiency of "Piku" as a larvicidal form. Fishes of this species kept by him in a fernery at Parel cleared that area of mosquito larvae.

18.* BARBER, M. A., KOMP, W. H. W. AND C. H. KING. 1929—Malaria and the Malaria Danger in Certain Irrigated Regions of southwestern United States. Pub. Health Rept. **44**(22):1300-1315, 3 refs. Great variability was observed in the effectiveness of Gambusia against Anopheline larvae in the drains, and there is some evidence that these fish are more effective against *Anopheles maculipennis* in Southern New Mexico and Texas than against *Anopheles pseudopunctipennis*. The breeding-places of the former appear to be more accessible to the minnows, whereas the mats of algae growing in the sun that are the preferred breeding-places of the latter may effectually protect the larvae against the fish. Moreover, in warmer climates *A. maculipennis* is more often found in the permanent waters of drains where Gambusia persists from year to year, whereas temporary rain and seepage pools usually harbour *A. pseudopunctipennis*. The wide distribution of Gambusia is, however, recommended, at least in the warmer climates.

19. BARNEY, R. L. AND B. J. ANSOM. 1921—Abundance of the Mosquito-destroying Top-minnow, *Gambusia affinis*. Especially in Relation to Male Frequency. Ecology **11**(1):53-69, 5 figs.

20. BARNEY, R. L. AND B. J. ANSON. 1922—The Seasonal Abundance of the Mosquito-destroying Top-minnow, *Gambusia affinis*, Especially in Relation to Fecundity. Anat. Rec. **22**(5):317-335, 9 figs. (Abstract in Expt. Sta. Record, Washington, D. C. **46**(8):750. 1922).

21. BARNICHOL, P. G. 1941—Food Habits of *Gambusia affinis* from Reelfoot Lake, Tennessee, with Special Reference to Malaria Control. Jour. Tenn. Acad. Sci. **16**(1):5-13, 9 refs.

22.* BEKLEMISHEV, H. N. AND G. E. RAEVSKII. 1935—On entomological Research concerning Malaria in provincial Institutions. III. Methods of utilizing Gambusia under conditions of a given Region. Med. Parasitol. **4**(4):327-328, 1 ref. This is the third part of an outline of a research program for subsidiary malaria stations in the Russian Union and deals with the utilization of Gambusia against Anopheline larvae in permanent and temporary accumulations of water. Factors to be considered in determining the prospects are briefly discussed.

23.* BENTLFY, C. A. 1910—The Natural History of Bombay Malaria. Journ. Bombay Nat. Hist. Soc. **20**:392-422. In connection with the malaria work in Bombay repeated experiments with Aitken's "Piku" fish was found very useful as a larvicidal form, provided it was present in sufficient numbers and was not hampered by floating weeds or rubbish. This species of fish was found particularly effective for clearing wells of mosquito larvae. Another species of fish "Kazari" (*Anabas testudineus*) which is also a surface-feeder, was found to be equally useful for destroying Anopheles larvae and pupae. The author recommended this species for stocking wells, tanks or ornamental fountains. *Polyacanthus cupanus* (*Macropodus cupanus*) was found to be larvivorous, but not as efficient as *A. testudineus*. Also "Chilwai" (*Chela argentea*) was found to be less efficient than the other three species enumerated above.

24.* BHASKER, RAO R. AND H. RAMOO. 1942—Some notes on the practical aspects of Mosquito Control in wells and tanks by the use of larvivorous Fish. Jour. Malar. Inst. India **4**(3):341-347, 1 pl., 2 refs. Various factors that might contribute to the disappearance of *Gambusia affinis* and *Aplocheilus* (*Panchax*) *parvus* from wells into which they have been introduced for the control of Anopheline larvae are reviewed in the light of observations made in Pattuk-kattae Taluk, Madras. In reservoirs, the native *A. parvus* seemed to survive without special measures, but *G. affinis* did so only if measures were taken to exclude larger predatory fish and to prevent this species from being washed away with the discharged water if the reservoir overflowed.

25.* BHASKER, RAO R. AND H. RAMOO. 1942—Observations on the relative utility of *Gambusia affinis* and *Panchax parvus* in the control of Mosquito breeding in wells and tanks. Jour. Malar. Inst. India **4**(4):633-634. It is concluded from laboratory and field experiments that *Gambusia affinis*, which has been acclimatized in India for 12 years has proved very useful for the control of mosquitoes breeding in wells and reservoirs in Pattus-kattae, Madras. *G. affinis* is easier to rear in large numbers than the indigenous *Aplocheilus* (*Panchax*) *parvus*. *G. affinis* consumes more larvae, thrives better in wells, is more effective in the wells and is more adaptable to diverse environmental conditions than the *A. parvus*, which is not suited for use in confined waters.

26. BINI, G. 1925—Relazione sulla lotta antimalaria di Fiumicino. (Report on the anti-malaria work at Fiumicino). 8vo, 93 pp., Rome, Coop. Tipogr. "Castaldi." Gambusia were stocked to prey on the mosquito larvae. No results were given as to the effectiveness of the fish.

27. BOETTGER, C. R. 1933—Ueber die Artzugehörigkeit des in Italien zur Malariabekämpfung eingeführten Zahnkarpflings. (On the Identity of the Species of Top-minnow introduced into Italy for Malaria Control). Zool. Anz. **105**(1-2):9-14, 21 refs. An investigation of the morphology of the species of Gambusia acclimatized in Italy for the control of mosquito larvae, showed it to be not *G. holbrooki*, as has been generally believed but *G. patruelis*.

28.* BOGDANOVICH, I. N. 1935—The Reproduction and Acclimatization of Gambusia in Turkmenistan. Med. Parasitol. **4**(5):413-416. (In Russian). In Turkmenistan,

where malaria is rife in many localities, the use of Gambusia against Anopheline larvae proved to be one of the cheapest and most reliable methods of controlling the disease.

29.* BOGOYAVLENSKII, N. A. 1936—Failure of Gambusia to destroy Anopheles larvae in Nature. Arch. Schiffs-u. Tropenhyg. **40**(5):201-203. In the Lenkoran district the Anophelines found are *Anopheles maculipennis* Mg., *A. hyrcanus* Pall., *A. superpictus* Grassi, *A. pulchirrimus* Theo., and *A. claviger* Mg. (*bifurcatus* auct.) the first named being the chief vector. A close association of Anopheline larvae and Gambusia was observed in various localities, but the larvae were not destroyed because of a great profusion of water plants which afforded mechanical protection for the mosquitoes and plenty of food for the fish.

30. BOGOYAVLENSKII, N. A. 1936—Existence simultance des Gambusia et des larves d'anopheles dans les eaux a vegetation limnique abondante. Med Parasitol. **5**(1):62-65. (In Russian).

31. BORA, E. 1921—Contributi alla Storia naturale degli Anofeli e alla Lotta biologica contro di essi (Contributions to the Natural History of Anophelines and to their Biological Control). Atti R. Accad. Naz. Lincei, Rend. Classe sci. fis. mat. e nat. **30**(4):122-125. The author's observations of the action of *Cyprinodon calaritanus* upon *Anopheles bifurcates* (*claviger*) appears unfavorable toward employing fish to destroy mosquito larvae.

32. BORTHWICK, T. 1923—An anti-mosquito Campaign in Adelaide. Health **1**(9):259-265, 1 fig. Among numerous control measures applied indigenous larvicidal fish, including *Melanotaenia nigrans*, *Priopis olivaceus* and *Carassiops galii*, were reared in large numbers to stock the waters.

33.* BOSE, K. 1925—An Extract from a Report on Mosquito Control at Birnagar. Calcutta Med. Jour. **20**(5):202-209. Tanks fully stocked with small fish, such as *Chela punctis* and *Anabas scandens* did not show any marked diminution of mosquito larvae.

34.* BOTO, R. 1932—Resultado das observacoes efectuados nos concelhos de Benaventi e Salvaterra de Magos sobre a distribuicas da Gambusia e a sua proavel procedencia. (The Result of Observations in the Municipalities of Benaventi and Salvatena of Magos on the Distribution of Gambusia and its probable Origin). Arq. Inst. bact. Cam. Pest. **6**(3):191-243, 18 figs., 5 diag., 1 map, 2 refs. Suitable breeding-places were free from *Anopheles muculipennis* Mg., and this was found to be due to *Gambusia holbrooki*, which had apparently come down the Tagus from Spain, where it had been introduced against mosquito larvae.

The second paper records the distribution of *G. holbrooki* in the district of Benaventi and confirms the introduction of this fish from the Tagus.

35.* BOTSFORD, R. C. 1930—Mosquito Control in Connecticut in 1929. Bull. Conn. Agric. Expt. Sta. **315**:608-613. Experiments were made in inland waters with the common killfish, *Fundulus heterocletus*, which is effective in mosquito control in salt marshes, and *Rhinichthy atronasus* (black-nosed dace), but the results were inconclusive.

36*. BOYD, J. E. M. 1920—The Value of Small Fish regarding the Destruction of Mosquito Larvae. Jour. R.A.M.C. **35**(5):406-409. Fish, especially surface feeders such as minnows and stickle-backs, destroy a considerable number of mosquito larvae, particularly in dykes and places where the latter are not protected by weeds. In recent observations the intestinal contents of *Gasterosteus pungituis* as many as seven larvae, probably of the species *Anopheles maculipennis* were found in one individual, the average number being two.

37.* BOYD, M. F. 1926—Studies of the Epidemiolcgy of Malaria in the Coastal Lowlands of Brazil, etc. Amer. Jour. Hyg. Monogr. Ser. **5**:v+261 pp. The author recommends *Poecilia vivipara* for a possible control measure in Brazil

38.* BOYD, M. F. AND F. W. ARIS. 1929—A Malaria Survey of the Island of Jamaica, B. W. I. Amer. Jour. Trop. Med. **9**(5):309-399. Most used fish found upon

the Island is the "Millions" fish, *Girardinus poeciloides*. Other usable fish found there are *Gambusia gracilior* and *Limia domincensis*.

39.* BOYER, L. 1928—Le Gambusia Prophylaxie du paludisme. Blanc et Gauthier, Rabat. (Reference incomplete).

40. BRAHMACHARI, B. B. 1909—Campaign Against Malaria Fevers at Cossipore-Chitpur Municipality. Calcutta Med. Jour. **3**:318. In Cossipore-Chitpur Bengal, it was found that in tanks clear of weeds, mosquito larvae were restricted to the edge of the fresh-water tanks where "Techoko" (*Panchax panchax*) were found preying on them in very large numbers. The author concluded that the importance of this agency when not interfered with by weeds in keeping down the malarial intermediaries cannot be exaggerated.

41. BREEMAN, M. L. VAN. 1919—De verbreidung van de malaria te Weltevreden in Batavia. Meded. Burg. Geneesk. Dienst Nederl.-Indie. **11**:1-40. (Text in Dutch and English). *Kepala timah* (*Haplochilus panchax*) reduced the larvae.

42. BRESLAU, E. AND FRANK GLASER. 1917—Sommerbekämpfung der Stechmücken. Zeits. angew. Entom. **5**(4):290-296. List of the fish used in Germany for mosquito control.

43. BRODIER, L. 1920—La lutte contre le paludisme en Algerie. Paris, medicale, la semaine du clinicien **37**:293-302. An indigenous fish of Berbera, *Cyprinodon iberus*, has been tried in Algeria for the control of mosquitoes. Although this fish is very voracious and an excellent larvae-eater, it is not able to destroy the larvae completely.

44.* BRUMPT, E. 1928—Role du poisson vivipare american, *Gambusia holbrooki*, dans la lutte contre la paludisme en Corse. C. R. Acad. Fr. **186**(13):909-911, 1 fig. The introduction of *Gambusia holbrooki*, under the direction of the author from Italy into Corsica in 1926 to destroy mosquito larvae has proved extremely successful. Very few larvae were collected in 1927 from places where in 1926 an average of 300 to 500 per square yard were taken. That satisfactory result was due to the fish and not to climatic conditions. This was proved by the investigation of four boats on a canal, all containing water, in three of which were found large numbers of mosquito larvae, while in the fourth, which contained a few Gambusia, accidentally introduced, not a single larvae could be found. The canal itself was well stocked with the fish, and larvae were extremely rare.

45.* BRUMPT, E. 1942—Notes parasitologiques concernant l'amenagement agricole de la Crau. Ann. Parasitol. hum. comp. **19**(1-3):74-78, 14 refs. The use of Gambusia against both Anopheles and Aedes is recommended.

46. BUEN, FERNAMDO DE AND SADI DE BUEN. 1922—Note sull'acclimatazione de la *Gambusia affinis*. Annali d'igiene **32**:281-285. A study of the effectiveness of Gambusia as mosquito destroyers in Spain.

47.* BUTLER, C. S. AND E. PETERSON. 1927—Malaria in Haiti. Nav. Bull. Med. **25**(2):278-288. *Poecilia sphenops* is the common larvivorous fish in the Haiti streams. Successful results were obtained by this control method. Other species of fish that are destructive to larvae are *Gambusia holbrooki*, *G. patruelis* and *G. dominicensis*.

48.* BUXTON, P. A. 1922—On Fish and Mosquitoes in Palestine. Bull. Ent. Res. **13**(2):203-204. The results of a study of the gut contents of the native fish revealed that mosquito larvae were completely absent from their diet.

49. CALDWELL, B. W. 1921—Use of small fish in the campaign against yellow fever in the Vera Cruz. Dept. of Public Health, Mexico City. Satisfactory results with the use of fish.

50. CANAUD, J. L. 1913—Destruction des moustiques a l'aide de certains poissons. Travaux publics **59-60**:145-157. Satisfactory results with the use of fish.

51. CARTER, H. F. RUSTOMJEE, K. J. AND E. T. SARAVANAMUTTU. 1927—Report on Malaria and Anopheline Mosquitoes in Ceylon. Ceylon: Sessional Paper **7**: 84 pp.

Several potentially valuable larvivorous fish belonging chiefly to the genera, Haplochilus, Barbus, Danio and Rasbora have been found in Ceylon, but the only indigenous species that has been tested in the field is *Haplochilus lineatus*. These fish appear to be definitely more abundant in the southwest, presumably on account of the numerous permanent swamps and pools. It appears that little is hoped for from the introduction of fish into the large areas of natural water in the dry zone without aiding their action by cleaning the weeds, etc., and it is therefore considered that their use should be limited to confined or temporary collections of water, such as wells, shallow flood areas, etc., since these situations are not only very numerous during the rainy season but are frequently prolific sources of Anophelines including the dangerous species, *A. culicifacies* and *A. listoni*. The imported fish, *Lebistes reticulatus*, has been established in several cases where it has been introduced. Attempts to establish *H. lineatus* have been less successful, and it appears less adaptable to changes of environment and does not thrive well in artificially treated solutions.

52.* CASTIGLIONI, A. 1927—Italy's Campaign against Malaria. Brit. Med. Jour. **3475**:278-279. *Gambusia affinis* was introduced where malaria was prevalent.

53.* CAUVET, 1925—Note sur les poissons susceptibles d'etre utilises dans la lutte contre le paludisme en devorant les larves de moustiques. Arch. Inst. Pasetur Alger. **111**(2):146-154. A short description is given of the various fish that might be used in Algiers for the destruction of mosquito larvae. The species dealt with include *Phoxinellus chaignoni*, which will live in an aquarium even in summer; *Tella apoda*, particularly adapted to live in small shallow pools, where it devours all the animalculae it finds; *Cyprinodon iberus*, which will live in an aquarium and is able to withstand great variations in temperature; and C. *fasciatus*, which is widely distributed and occurs in more or less brackish waters.

54.* CHAMBERLIN, R. V. AND D. M. REES. 1935—Survey of Mosquitoes and Mosquito Abatement Work of Salt Lake City, 1934. Multigraphed, Salt Lake City. A detailed account is given of the seasonal prevalence of the mosquitoes in Salt Lake City in 1934, and of the various anti-larval measures including drainage, oiling and the distribution of *Gambusia affinis*.

55. CHAUDHURI, B. L. 1909—Mosquito-larvae-eating Propensity of the Genus Haplochilus. Jour. and Proc. Asiat. Soc. Bengal **5**:36-37. An investigation of the mosquito-larvae-eating propensity of fishes of the group Haplochilus revealed that these tiny surface swimming fishes possess ravenous appetite for living and moving larvae in water, and that they eat the wriggling larvae of mosquitoes with great avidity. The author found that even under natural conditions these fish are equally efficient for destroying mosquito larvae. Experiments were being conducted to determine the numbers of fish that would be required for keeping an area of known dimensions, of a stagnant or confined nature, free of mosquito larvae.

56. CHAUDHURI, B. L. 1911—Fish and Mosquito Larvae. Calcutta Med. Jour. **6**:457-470. The author dealt in general with the various steps suggested for the control of mosquito larvae in permanent breeding grounds and strongly condemned the use of larvicides of chemical nature for mosquito control in waters containing fish and other animals. He recommended the improvement of the drainage in such localities, as he believed that by drainage they are made particularly suitable for fish. He gave an account of his experimental work with the indigenous fishes for determining their larvivorous propensities and outlined the necessary characteristics of fishes to be selected for such work; these, with slight modifications, have been adapted by the Malaria Survey of India as a standard. The species, which he found particularly useful for larvicidal work, were *Haplochilus panchax* (*Panchax panchax*), *Badis badis*, *Ambassis nama*, *Trichogaster fasciatus* (*Colisa fasciatus*), *Anabas scandens*, (*A. testudineus*), *Barbus phutnio*, *Nuria danrica* (*Esomus danricus*), *Notopterus kapirat* (*N. notopterus*) and *Rasbora daniconius*. He also considered *Perilampus atpar* (*Laubuca atpar*) and *P. laubuca* (*Laubuca laubuca*) as being of some practical utility. Chaudhuri's paper contains a very useful review of the whole subject, while the information regarding the local names and habits of the different species makes it especially valuable for reference.

57.* CHIDESTER, F. E. 1917—A Biological Study of the more important of the Fish Enemies of the Salt-marsh Mosquitoes. N. J. Agric. Expt. Sta. Bull. **300**: 16 pp., 1 plate, 2 figs. The following fishes are known enemies of mosquitoes: *Fundulus heteroclitus, F. majalis, F. diaphanus, Gambusia affinis, Cyprinodon variegatus, C. ca!aritanus, Heterandria* sp., *Abramis chrysoleucus, Carassius auratus, Eupomotis gibbosus, Molliensia latipinna, Girardinus poeciloides, G. caudimaculatus* and *Haplochilus* sp. Of these, by far the most important is *Fundulus heteroclitus*, known under various popular names, including killfish and salt-water minnow. It is the most voracious enemy of mosquitoes in all stages and eats the larvae of the water-beetle, Dytiscus, and the water-bug, Notonecta, though the number of these mosquito enemies destroyed by it is relatively negligible. The importance of this species lies in the fact that it migrates from the ocean to the shallow, and even into almost fresh water, in vaste hordes, and also that it may be artificially fertilised, the young embryos being remarkably vigorous and hardy, rendering the stocking of pools and streams with this species a simple matter.

58. COLLADO, J. G. 1929—Anofelismo en el delta de Ebro. Med. Paises Calidos **11**(5):436-438. *Cyprinodon hispanicus* was used as a control measure.

59.* CONNOR, M. E. 1920—Yellow Fever Control in Ecuador. Preliminary Report. Jour. Amer. Med. Assoc. **74**(10):650-651. One of the perch family was found to be a voracious destroyer of the larvae but its habits of jumping three or four feet out of the water in order to escape led to its replacement by two other native species, which yielded good results.

60.* CONNOR, M. E. 1921—Fish as Mosquito Destroyers. An Account of the Part they played in the Control of Yellow Fever at Guayaquil, Ecuador. Nat. Hist. **21**(3): 279-281. During the yellow fever campaign in Ecuador, various fish were experimented with as destroyers of mosquito larvae. Top minnows (Gambusia) were not found sufficiently hardy, and eventually, of several native fish tried, one known as the "chalaco" was selected as being the most useful in this connection. Arrangements were therefore made for its continued distribution to all water containers in Guayaquil. More than 30,000 water receptacles have been freed in this manner from mosquito larvae.

61.* CONNOR, M. E. 1922—Notes on the Use of Freshwater Fish as Consumers of Mosquito Larvae in Containers used in the House, based upon Experience in Guayaquil, Ecuador, and Merida, Yucatan, Mexico, Amer. Jour. Public Health **12**(3):193-194. This is a condensed account of the author's experience with larvicidal fish in many campaigns against yellow fever. Points that make the use of fish effective are enumerated. Top-feeders are best for open-air fountains and collections of water of a similar nature, while bottom feeders are best for tubs, barrels, etc., in the house. Apparently no fish will live in metal tanks; for these, tight-fitting lids must be provided.

62.* CONSOLI, N. 1934—La lotta control la malaria in Sicilia durante l'anno 1932 e l'azoine svolta dal Provveditorato alle Opere (Anti-malarial work in Sicily in 1932). Riv. Malariol. **13**(4):487-530, 16 pls. Gambusia used with success.

63.* COOLING, L. E. 1923—Mosquito-larvivorous Fishes in Relation to Mosquito Reduction Work in Australia. Health **1**(4):94-98. All permanent fresh waters of Australia that have been untouched by men harbour fish that devour mosquito larvae. Generally speaking, the average type of marsh with fairly well defined edges does not breed mosquitoes because of the fishes with which it abounds.

Malanotaenia nigrans is one of the most widely distributed larvicidal fish in eastern Australia. Others are *Priopis olivaceus* and *Carassiops* (*Austrogobio*) *galli. Pseudomugil signifer* occurs in both salt marshes and fresh waters, and though it displays marked predatory habits in fresh water aquaria, its presence in a salt marsh is not always indicative of the absence of larvae of *Aedes* (*Culex*) *vigilax* Skuse, *C. sitiens* Weid., and *Mucidus altermans* Westw. It is possible that in these cases it finds a greater variety of diet in marine forms such as the smaller Crustacea.

The only importance that can be attached to fish such as *Carassiops compressus* is that they are valuable indicators of pollution and purification in field observation work on mosquitoes. When streams become polluted, as by sewers discharging into them, the water is deoxidized; this has no inimical effect on the larvae of such mosquitoes as

Culex fatigans Weid. (*quinquefasciatus* Say), but fish cannot survive. *C. fatigans* transmits *Filaria bancrofti*, so that the reduction of filariasis in Queensland is co-ordinated with municipal drainage undertakings, as measures guarding against the stagnation of sewage in any form considerably reduced the numbers of the mosquito.

64. COOLING, L. E. 1923—Report on Mosquito Survey of the Brisbane Metropolitan Area. Australia Dept. Health, 43 pp., typescript, 3 maps. The commoner mosquitoes found in the Brisbane area in the course of this survey included *Aedes argenteus* Proir (*aegypti* L.), *Culex fatigans* Weid. (*quinquefasciatus* Say), *C. sitiens* Weid., *Aedes* (*Ochlerotatus*) *vigilax* Skuse, *Mucidus altermans* Westw., and *Anopheles annulipes* Wlk. Domestic mosquitoes do not breed in fresh water marshes and streamlets in the natural state in southern Queensland on account of larvivorous fish with which they abound. When the activities of the fish are impaired by aquatic vegetation, a few Anopheline larvae (*A. annuliples*) can generally be found, and some of rarer Culicines. It is during periods of protracted drought, when natural waters are covered with aquatic vegetation, and particularly with hyacinth that the maximum amount of Anopheline development is observed. If streamlets become polluted by sewage so that the fish are killed, domestic species of mosquitoes are able to breed in them.

65. COOLING, L. E. 1927—Australian Fish as Mosquito Larvae Destroyers. Health **6**(1):11-12. Reference is made to an attempt on the part of the Germans to introduce Australian larvicidal fish into New Guinea, which after two failures proved successful in 1914, when four species of fish were imported from Sydney into the Bismarck Archipelago.

In addition to the fish previously noticed in Australia, the family Centropomidae (including the genus Ambasis) is stated to contain good larvae destroyers.

66.* COULON, G. AND J. SAUTET. 1931—*Gambusia holbrooki* et paludisme en Corse. Resultats de six années de lutte antilarvaire au moyen des poissons culiciphages. Ann. parasit. hum. comp. **9**(6):530-545, 8 figs., 9 refs. An account is given of the results obtained from the distribution and maintenance of the larvicidal fish, *Gambusia holbrooki*, in all important Anopheline breeding-places, which have been carried out as an anti-malarial measure in Corsica during the last six years with beneficial results and comparatively little expenditure. In the coastal regions and low-lying valleys, which are of particular interest from a malarial point of view, conditions are very favorable for the growth and multiplication of this fish, and the climate, with mild winters and warm summers, is very suitable. Moreover, there are no really formidable natural enemies. The fish can adapt itself to salt waters and tolerates a higher degree of salinity than Anopheline larvae. The best results are obtained in permanent collections of water, such as garden wells, marshes with or without drainage canals, and pools formed by flooding that only communicate with the rivers at times of flood. It is most effective in summer and autumn; in spring its work should be supplemented by such measures as clearing of vegetation and application of Paris green. In seasonal breeding-places, results are very effective and diminishes the work necessary in anti-larval campaign. Supplies of fish should be kept to re-stock breeding-places that dry up during the summer, and where possible fish-ponds should be dug at the lowest point of marshes to ensure abundant re-stocking when the water re-appear.

67.* COVELL, G. 1927—Anto-mosquito Measures. Malaria Bureau No. 3, Health Bulletin **11**, Calcutta. (Paper is based upon Chaudhuri's work).

68. COVELL, G. 1935—Anti-mosquito measures with special reference to India. Malaria Bureau No. 3, Haelth Bulletin **11**:1-60. Calcutta.

69.* DANILOVA, M. I. AND G. I. LAPPIN. 1936—Sur le transport des Gambusia. Med. Parasitol. **5**(4):579-583, 5 refs. Experiments to find the optimum conditions for transporting Gambusia were carried out in Sukhum in 1935. It was found that for a journey of up to 8 days, the fish may be kept at the rate of 20 per litre of water (90 per gal.) in open receptacles, allowing free access of air, at a water temperature not exceeding 13-16° C. (55.4-60.8° F.). Covered receptacle stocked with fish at the same rate should be only half filled with water, and the water in them should be kept cool since mortality among the fish is low at 6-8° C. whereas almost all die at 14-20° C.

In all cases dead fish should be removed as often as possible. Other conditions being equal, the best receptacles are those that expose the largest area of water surface to the air. The fish can withstand starvation for considerable periods. Special experiments showed that they are not affected by the presence in water of iron oxide from rusty containers. They thrived in water with a salinity of up to 1.5 per cent, provided that there was suitable aquatic vegetation; in the absence of the latter, they began to die, at a salinity of 1 per cent.

On the basis of these experiments, about 180,000 fish were transported in large wooden barrels, by steamers from Sukhum to Rostov-on-Don, and from there to a number of districts. They multiplied in various collections of water in the course of the summer and migrated under the ice in December.

70. DAVIS, N. C. 1927—Antimalarial campaign at Medinas. Prelim. Rept. after the first year's work (co-authors are Lobo and Cabarrou). Sem. Med. **34**(1728):467-485. In the Medinas *Fitzroya lineata* is considered the most effective fish.

71.* DE BUEN, E. 1929—Estudio experimental de algunas substancias larvicidas antianofelicas (An experimental Study of some larvicidal Substances against Anophelines). Med. Paises Calidos **2**(5-6):401-430, 508-540, 14 figs., 3 diagr., 54 refs. An account is given of field and laboratory experiments with various oils and other larvicides and with Gambusia for the control of *Anopheles maculipennis* Mg., which is the only vector of malaria in the Spanish province of Caceres. It is concluded that the best results are obtained by using Gambusia and supplementing its action by means of Paris green. All collections of water, however small, are stocked with the fish and then dusted every ten days, the presence or absence of the fish being noted so that the supply may be renewed if necessary. The cost of the combined method is very little higher than that of dusting alone. It was found that ponds containing Gambusia only had to be dusted once in June and did not need dusting in July, August or September, whereas other ponds required dusting from March to October.

72. DE BUEN, F. 1930—Notas sobre la fauna ictiologica de nuestras aguas dulces. (Notes on the Fresh-water Fish Fauna in Spain). Notas y Resumenes Minist. Fom. (Spain) Ser. **2**(46): 62 pp., 71 figs. These notes deal briefly with the fish found in channels, rice-fields, and slow-moving streams in Spain in which Anopheline breed. The species discussed include *Gasterosteus aculeatus*, which feeds voraciously on insect larvae but also destroys other fish, and *Gambusia holbrooki*, which has become established since its introduction for the control of Anopheline larvae.

73. DEPT. OF AGRICULTURE, ST. VINCENT. 1917—Work in the Botanic Gardens, and Observations on Plants. Rept. Agric. Dept., St. Vincent for 1916-1917: 1-3. Barbados. It is stated the *Girardinus poeciloides* (millions fish) continues to thrive in a lily pond in the gardens, keeping down mosquito larvae. Fish from this pond introduced into swamps in two malarial districts have become well established, while in three other similar localities, though they have not been seen since their introduction, there is every reason to hope that they will survive and prove of value in mosquito control.

74.* DERWALD, W. F. 1919—New Jersey's work in mosquito control. Jour. Amer. Med. Ass. **73**:737-741. *Fundulus majalis*, *Fundulus diaphanus* and *Cyprinodon variegatus* or sheephead minnow have been especially studied by the New Jersey Agricultural Experiment Station in both the field and laboratory in relation to mosquito control.

75.* EIGENMANN, C .H. 1923—Yellow Fever and Fishes. Amer. Natur. **57**(652): 443-448, 5 figs. *Lebistes* (*Acanthophacelus*) *reticulatus* is believed to have been responsible for the absence of yellow fever in Trinidad. In North America Gambusia is the chief larvicidal fish. Beside *L. reticulatus*, the most useful ones in South America are *Pygidium piurae*, *Lebiasina bimaculata* and "Chalacoa."

76.* EIGENMANN, C. H. 1924—Yellow Fever and Fishes in Colombia. Proc. Amer. Phil. Soc. **63**(3):236-238. In Peru the fish most effective in destroying mosquito larvae is *Pygidium piurae*, which is active at night. In Colombia a smaller species, *P. striatum*, is utilised, as well as *Piabucina panamensis*, which has an extremely wide distribution. A fish used on the Pacific slope is *Dormitator latifrons*, an allied species in

Barrabquilla and along the Atlantic slope generally being *D. maculatus*. The former has proved very effective and there is every reason to believe that the latter will be equally so, if it is found in sufficient abundance. Another fish that is being tried in Colombia is *Geophagus steindachneri*. Two species of "catfish," *Pimelodella chargrensis* and *Rhamdia sebae*, are also being used in Colombia. *Mollienisia caucana*, abundant in the swamps of the lower Magdalena basin, is a minute fish that for *a priori* reasons should be extremely useful. Species of the Poecilidae, to which family the genus Mollienisea belongs, and which contribute mosquito eradicators elsewhere, are widely distributed in Colombia. Along the coasts of the Guianas they are especially abundant both in species and numbers.

77.* EGGERT, E. G. 1920—*Gambusia affinis*. Texas Health Mag. 1(3):7-10. Gambusia may be employed in such waters as stock ponds, watering troughs, surface reservoirs, and the like, where oiling and draining are impractical.

78.* EMERICK, A. M. 1942—Mosquito Fish. Proc. 12th Calif. Mosq. Contr. Ass.: 128-129. A report is given of the establishment of Gambusia against mosquito larvae in all the ponds of the Calistoga sewage farm, California. The fish were first introduced into the lowest and cleanest pond in 1933, and as they became acclimatized, they were moved up every six months, until they were established in all the ponds and even in the septic tanks. They are very effective. The edges of the ponds are kept clear of grass by a small flock of sheep. While admitting that fish cannot effectively be used where algae are abundant, the author states that the algae can be controlled by the use of copper sulphate.

79.* ENIKOLOPOV, S. K. 1935—Observations on the Biology of Gambusia that have been acclimatized in Daghestan. Med. Parasitol. 4(5):408-413, 2 figs., 2 refs. Since its introduction for the control of mosquito larvae in Daghestan in 1928, Gambusia has become well established and widely distributed in the plain. There are now 8 permanent breeding ponds in which the fish hibernate and from which they are sent to other districts. Observations in concrete tanks in the town of Maklach-Kala on the Caspian Sea, showed that a female may produce up to 6 broods comprising a total of over 920 young between mid-June and the beginning of September, the intervals between broods being 21-25 days during the first 3 months. In the course of the summer, the fish of the first and second broods also produce offspring. The maximum production of young occurred in the beginning of June at a mean temperature of 15° C. (59° F.). Two or three broods could be produced after one fertilization, which is of importance, since no males may occur among the few fish that are frequently liberated in small pools in the country, though the sex ratio was found to be 1:1. Sexual dimorphism became apparent 36 days after birth, and young fertilized females produced young 17 days later.

The development of the fish chiefly depends on the supply of food and to a less extent on the temperature. Fish in which the sexual characters had just become apparent readily swallowed mosquito larvae of the first three instars, but not those of the fourth instar or pupae. No cases of cannibalism occurred in reservoirs with an abundance of food, whereas if it was scarce and the water devoid of vegetation, all the young fish were eaten by the parents in less than 24 hours. In the course of a night an adult female was able to eat 94 pupae of Aedes, or 109 fourth instar larvae of Aedes, Culex and Anopheles. Fish one month old destroyed 20 fourth instar larvae of Aedes in 24 hours. Young fish dissected from females that had just died continued to thrive.

80. FEBRICI, E. 1921—Fighting mosquitoes with fish. 7th Ann. Rept. Intern. Hlth. Bd. Rockefeller Foundation: 20-27, New York.

81. FERMI, CLAUDIO. 1919—Fish and malaria control. La lotta control la malaria mediante la grande e piccola bonifice e la disinfectione idro-aerea antianofelica. 62 pp. Roma. In the numerous experiments which have been tried, the goldfish, chub, and stickle-back have been found useful. In the districts around Rome, Brunelli has found *Cyprinodon calaritonus* (Nonni) and *Gasterosteus aculeatus* satisfactory. The Nonni are apparently excellent larvae-eaters because they can live in shallow and somewhat warm collections of water.

82.* FERMI, C. 1933—Diserbo biologico delle acque. (The Biological Clearing of Aquatic Vegetation). Riv. Malariol. **12**(3):523-531, 5 refs. A sheet of water in Sardinia, which covered about 150 acres and in which mosquitoes bred prolifically was so full of aquatic vegetation that in some parts even *Gambusia holbrooki* was unable to penetrate. As a result of stocking with carp, the plants were completely cleared away and no mosquito larvae could be found. Their absence is attributed primarily to the free movement of the water and not to the presence of Gambusia.

83. FISHER, H. C. 1924—Report of the Health Dept. Panama Canal for 1923. 95 pp. In the Panama Canal, the minnow *Poecilia sphenops* is quite abundant and is very voracious on mosquito larvae.

84. FLU, P. C. 1912—Rapport over het wetenschappelijk onderzoek narrhet voorkomen der kolonie Suriname an de bestrudeering van dis ziekte. s'Gravenhaag, Algemeene Landdrukkerij, 124 pp. In inspections of Lelydorp, mosquito larvae have never been found in rice-fields where *Girardinus guppii*, a native of Dutch Guiana, was present in the water.

85.* FRATANI, L. 1939—Etude epidemiologique du paludisme a Beni Abbes (Sahara oranais) in 1937. Arch. Inst. Pasteur Alger. **17**(3):429-437, 2 pls., 1 map, 5 refs. Gambusia was introduced. The fry of a local fish, *Barbus figuiensis*, were found to destroy mosquito larvae. No larvae were found in the pools in which they were present, and although they are less active than Gambusia, they are well adapted to local conditions.

86.* FRY, A. B. 1912—Indigenous Fish and Mosquito Larvae Paludism. Trans. Comm. Study Malaria in India **5**:71-74. Common larvicidal fishes of Bengal fresh water are *Haplochilus panchax* (*Panchax panchax*), *H. melastigma* (*Aplocheilus melastigma*), *Ambassis nama*, *A. ranga*, *Barbus ticto*, and several species of the genus Trichogaster (Calisa and Trichogaster). As a result of his work he observed that permanent waters with any of these larvicidal forms present, if free of weeds and with clean cut sides without grass or bush and with no shelving mud flats, were found to be free of larvae. Culex and Anopheles larvae are found in abundance if excessive and thickly matted weeds are present, while only Anopheline larvae are found if the weeds are not very excessive and the edges are shelved. In his opinion, indigenous fish were sufficiently numerous to deal with mosquito larvae and importation of exotic species was unnecessary.

87. GALLI-VALERIO, BRUNO AND JEANNE ROCHAZ-DE JONGH. 1903—Studi e ricerche sui culicide dei generi culex e anopheles. Atti Soc. studi d. malaria **4**:3-48. (From 1903-1908, the outhors made a series of experiments that were disconnected and not very conclusive). These writers confirmed the observations of Underwood to the effect that goldfish (*Carassius auratus*) are useful in tubs, casks and small ponds. They stated that *Phoximus laevis* and *Telestes muticellus* are both excellent eaters of larvae. Their observations upon them seem to have been made in tubs. By some experiments made both in tubs and in two small pools, they concluded that *Cyprinus prasenus* and *Cobitis barbotula* are valuable in the destruction of larvae. They never found mosquitoes in small ditches with green algae and fish.

88. GAMMANS, L. D. 1926—Anti-Malaria Work at Port Dickson. Malayan Med. Jour. **1**(2):24-28. An uncemented pool, which could not be oiled, was treated by introducing a larvicidal fish (*Hoplochilus panchax*).

89.* GEIGER, J. C. AND W. C. PURDY. 1919—Experimental Mosquito Control in Rice-fields. Jour. Amer. Med. Assoc. **72**(11):774-779. During 1918 observations in Arkansas, extending over the entire rice-growing season from June to September inclusive, showed that Anopheles and Culex were present in equal and moderate abundance; breeding was fairly uniform over the entire field, with a slight preference for the more open water along embankments beginning 10-14 days after flooding and continuing until late in September, when it gradually diminishes. Top minnows are usually found near the embankments and water-outlets, rarely in mid-field.

As a result of the experiments detailed here the conclusions reached are that intermittent flooding as a remedial measure is probably not feasible owing to the additional

cost of water and to the usual impossibility of the transference of the larvae beyond flight distance. Owing to the preference of top-minnows for deeper water they are of doubtful value; nevertheless their presence means a considerable reduction in mosquito larvae.

90.* GEIGER, J. C. AND W. C. PURDY. 1920—The malaria problem of the rice-fields of the United States. Southern Med. Jour. **13**:577-582. The tremendous area of rice-fields and the abundance of obstacles diminish the usefulness of small fish, although in drainage ditches they may be entirely satisfactory.

91.* GIBSON, A. 1927—Mosquito Investigation in Canada in 1926. Proc. 14th Ann. Mtg. N. J. Mosquito Exterm. Ass.: 110-115, 2 pls. The small top-minnow, *Gambusia affinis*, imported into Banff, Alberta from California, survived the winter in warm sulphur pools, and is apparently breeding freely.

92. GILCHRIST, J. D. F.1913—The introduction of millions. In Cape of Good Hope, Marine Biological Report for the year and a half ending June 30, 1913, **1**:67-70. In Jamaica the use of gold-fish has been suggested to supplement the millions, which are, however, said to be successful,

93. GIOSEFFI, M. 1919—Per la lotta contro la malaria in Istria: contribrito alla conoscenza della condizioni igienico-sociali dell' Istria. Reforma medica **35**:671-675. Gioseffi failed to attain any success in some experiments in Brioni and Barbariga where sticklebacks (*Gasterosteus enneaculeatus*) were used in a lake.

94. GIOSEFFI, M. 1922—La Malaria in Istria nel 1920. Il Policlinico, Sez. prat. **27**:920-924. In winter no mosquito larvae were found in swamp water. The first larvae of Culex and Anopheles appeared in April. Owing to the exceptional drought no Anophelines were observed after August. No larvae were found in a pool where fish had been placed in the previous year.

95.* GIOSEFFI, M. 1926—Le "Gambusie" nella lotta antimalarica in Istria. (*Gambusia affinis* in antimalarial Work in Istria). Riv. Malariol., N.S. 1, **5**(4):469-475. Experience has shown that *Gambusia affinis* is effective in combating Anopheline larvae in Istria. This fish has easily become acclimatized there, and has survived the hot summers and winter frosts of 1925-1926. It has practically caused the disappearance of larvae in collections of water, and has reduced the endemic malaria.

96. GOELDI, E. A. 1905—Os mosquitos no Para. Mem. Museu Goeldi **14**: 154 pp. The author recommended that fish be used in containers of still water where mosquitoes were apt to breed. He favored certain local varieties about three inches long, which he said to be able to devour an astonishingly large number of larvae.

97.* GORGAS, W. C. 1915—Vegetation and fish control. In his Sanitation in Panama: 159-160. New York. If the water was accessible and clear of grass, the native fish destroyed all the larvae.

98.* GOWDY, C. C. 1912—Fish preying upon mosquito larvae in Uganda. Bull. Ent. Res. **2**:182.

99.* GRAHAM, W. M. 1912—A fish that preys on mosquito larvae in Southern Nigeria. Bull. Ent. Res. **2**:137-139.

100.* GRASSI. B. 1923—Pesci nostrali antimalarici. (Italian larvicidal fishes). Atti R. Accad. Naz. Lincei, Rend. Classe sci. fis., mat. e nat. **32**:511-513. The conclusion reached in this review of the various attempts made in Italy to use indigenous fishes against mosquitoes is that little can be expected from these species. Two exotic species, *Girardinus poeciloides* (millions) and *Gambusia affinis* (Top-minnow) are worthy of tests on a large scale.

101.* GRASSI, B. 1923—Acclimazione delle Gambusie in Italia. (The Establishment of *Gambusia affinis* in Italy). Atti R. Accad. Naz. Lincei, Rend. Classe sci. fis. mat. e nat. **32**:544-548. The tests with *Gambusia affinis*, brought to Rome from Spain in July 1922, seem to indicate that this fish may prove of real value in destroying mos-

quitoes in Italy, but it is unable to penetrate dense aquatic vegetation and frogs prey on it.

102. GREEN, H. W. 1921—Preliminary report on Anopheles mosquito reduction and its relation to malaria control in Aquirre, Porto Rico; with notes on methods used and results observed in 1921. (Typewritten). 175 pp.

103. GUITERAS, JUAN. 1915—Insect borne diseases in Pan-America. Havana Department of Health. 42 pp. (Sanidad y beneficencia, Botelin oficial. **15**:93-132. 1916, Habana). Indigenous fishes compared to the exotic species in controlling mosquito larvae.

104.* HACKER, H. P. 1923—Malaria Bureau Annual Report, 1922. F. M. S. Med. Rept. 1922. Suppl. to F. M. S. Gov't. Gaz.: 16-22, Kuala Lumpur. Experiments with fish showed that (*Cyclocheilichthys apogon*) would eat mosquito larvae only in the absence of preferred food (micro-organisms, algae, etc.) but *Betta pugnax* was found to eat the larvae with avidity, and further experiments are to be made with this fish.

105.* HACKETT, L. W. 1931—Recent Developments in the Control of Malaria in Italy. Jour. S. Med. Assoc. **24**(5):426-430. Introduction of Gambusia from United States has led to unexpected results. No horizontal vegetation, however thick, can protect anopheline larvae from the fish, large and small, which constantly patrol every square inch of water surface. On the area of about 8 square miles which we have had under observation for five years in Istria, the spleen index in a scattered rural population has gone down from 98 per cent in 1924 to about 10 per cent in 1930. Nothing but gambusia distribution has been done in this area.

106. HAMLY-HARRIS, R. 1929—Relative value of larval destructors and the part they play in mosquito control in Queensland. Proc. R. Soc. Queensland **41**(3):23-38. *Craterocephalus fluviatilis* was used as a biological control measure.

107. HANCOCK, G. L. R. 1927—Annual Report of the Assistant Entomologists. Rept. Dept. Agric. Uganda **1926**:27-29. The most likely fish to be of practical importance is a species of Haplochromis, probably *H. nubelis*, which consumed large numbers of Anopheline and Culicine larvae in the laboratory.

108.* HANSON, H. 1925—General Report on the Yellow Fever Campaign in Colombia, May 1923 to December 31, 1924. Amer. Jour. Trop. Med. **5**(6):393-400. In the course of the campaign 908, 655 houses were visited, in 69, 690 of which *A. argenteus* was found breeding, chiefly in containers; and 364,926 larvicidal fish were distributed. *Geophagus steindachneri* did not prove of much value, but *Piabucina panamensis* was effective; *Pimelodella chagresi*, *Dormitator* sp. and other fish were also used. The use of fish in Colombia was not so successful as in Peru, the fish being less hardy species.

109.* HANSON, H. AND L. H. DUNN. 1925—The Use of Fish in the Control of Yellow Fever in Peru. Milit. Surgeon **57**(3):232-241. Experiments made in Peru in 1921 and 1922 with fish against the yellow fever mosquito, *Aedes argenteus* (*aegypti*), are described. A local species, *Pygidium piurae*, feeds voraciously on the larvae and pupae. It survives crowding in the pails and cans used for transport purposes and rapidly adapts itself to life in containers. More than 80 per cent, of some 857,000 fish distributed belong to this species.

110.* HARDENBURG, W. E. 1922—Fish Control. Chapter IX of "Mosquito Eradication": 172-194. McGraw-Hill Book Company, New York. The author cites the advantages and limitations of the following in relation to mosquito control: *Gambusia affinis*, *Fundulus heteroclitus*, *F. majalis*, *F. diaphanpus*, *F. notatus*, *F. notii*, *Cyprinodon variegatus* and *Lucania parvia*.

111.* HASLAM, J. F. C. 1925—Observations on the Experimental Use of Fish indigenous to British Guiana for the control of Mosquitoes breeding in Vats, Tanks, Barrels and other Water Containers. Jour. Trop. Med. and Hyg. **28**(15):284-288. As the practice is fairly common in British Guiana of keeping one or more fish (nearly always *Hoplosternum littorale*) in water receptacles, a study has been made of the

various indigenous fish that might be of value in mosquito control. The mosquitoes found breeding in the water receptacles were *Aedes argenteus* (*Stegomyia fasciata*) and *Culex fatigans* with occasionally, *Anopheles tarsimaculatus*. The trials with the various fish are described and the results tabulated. Silverbait (species of *Tetragonopterus*, *Charax*, *Hemigrammus*), *Hoplosternum littorale*, and *Cichlasoma bimaculatum* appear to be of the greatest value in this respect. For the smaller domestic water-containers silverbait are particularly useful, especially as they are able to live in water without the presence of mosquito larvae; for large vats or tanks the other species are more suitable. The advantages and disadvantages of each are briefly discussed.

112.* HASLAM, J. F. C. 1926—Report on Experimental Use of Fish indigenous to British Guiana for the Control of Mosquitoes breeding in Vats, Tanks, Barrels, and other Water Containers. Br. Guiana, C. S. O., No. 3579/25, fol. 8 pp., Georgetown. Of a number of kinds of fish experimented with under natural and laboratory conditions, the most satisfactory for use in mosquito control in British Guiana include *Hoplosternum littorale*, *Cichlasoma bimaculatum* and silverbait (*Tetragonopterus chalceus*, *Charax gibbosus*, *Hemigrammus rodwayi* and *Hemigrammus unilineatus*). The silverbait are the most suitable for small domestic water-containers: they are voracious feeders, devouring all stages, and they are easily obtained. Their use by villagers is proving most satisfactory, particularly as it does away with the continual rescreening of vessels. The other two species do well in large vats and tanks.

113.* HAYES, T. H. 1930—Report of Mosquito Survey in St. Croix. U. S. Naval Med. Bull. **28**(1):194-222, 1 map. The most effective natural enemy of mosquito larvae is the fish, *Lebistes reticulatus*, which was imported from Barbados in 1902. Other natural enemies and remedial measures that have been found effective in other countries and might prove applicable to St. Croix are recorded.

114. HAYLING ISLAND. 1922—Report of the Proceedings of the Hayling Mosquito Control from Sept. 1920 to June 1922. 12 pp. Southsea. The anti-mosquito work at Hayling Island during 1922 included experiments with fish as destroyers of the larvae. In connection *Gobius microps*, found in sea-filled ditches, gave promising results as a possible check upon the activities of *Aedes* (*Ochlerotatus*) *detritus*.

115.* HEARLE, E. 1928—Mosquito Control Activities in Western Canada. 58th Ann. Rept. Ent. Soc. Ontario 1927, pp. 45-50. Toronto. The author states that *Gambusia affinis* has thrived well in warm sulphur pools and large numbers were placed in the lakes, but that it had been impossible to find out whether the fish had acclimatized itself in the cold water.

116.* HEGH, E. 1921—Les Moustiques, Moeurs and Moyens de Destruction. Bruxelles. 237 pp., 280 refs. General control measures.

117. HANDLEY, COL. H. 1917—Report on Malaria in the Punjab during the Year 1916, together with an Account of the Punjab Malaria Bureau. Supt. Gov't. Printing, 18+xxxiv pp., 3 charts, 4 maps, Lahore. At Kates, in the sacred tank, larvae were found to abound side by side with innumerable fish (*Cirhina latia* and *Barbus terio*) which, especially when young, are destroyers of mosquito larvae. A similar result was met with at the Shalamar Gardens at Lahore, where larvicidal fish had been specially introduced.

118.* HENN, A. W. 1921—The large-mouthed black bass in mosquito control. In his notes on classification of fishes accompanied by a letter to E. C. Meyer dated New York, May 23, 1921. The United States Bureau of Fishes, because of the danger to native and useful species, sometimes declines to furnish bass and other fish that might do more harm than good.

119. HENSON, G. E. 1913—The Use of Fish in Mosquito Control. In his Malaria: Etiology, Pathology, Diagnosis, Prophylaxis, and Treatment: p. 145. St. Louis.

120.* HERMS, W. B. 1928—Limitations in the Use of Top Minnows in Anopheles Mosquito Control in California and Observations on Anopheline Flight Activities. Southern Med. Jour. **21**(9):761-762. In a large percentage of Anopheline breeding-

places in California, it is difficult to maintain effective control by means of Gambusia, on account of winter floods that carry away the minnows. The pools left by the receding streams are prolific sources of Anophelines. Arrangements are being made in one locality to keep several thousand minnows in a concrete tank during the winter for repopulating streams after the winter floods.

121.* HERMS, W. B. 1934—Mosquito Control in California under the CWA. Jour. Econ. Ent. **27**(5):1014-1029. An account is given of work done under the Civil Works Administration in mosquito control in California from December 1933 to April 1934. About 57 miles of drainage ditches were constructed. The banks were cleared, swamps filled in and tide-gates and culverts repaired. Large numbers of Gambusia were distributed, and many potential breeding-places were eliminated. A list of 15 species of mosquitoes collected is given.

122.* HERMS, W. B. AND H. F. GRAY. 1944—Mosquito Control. The Commonwealth Fund. 420 pp. New York City. General control methods.

123.* HESS, A. D. AND C. M. TARZWELL. 1942—The Feeding Habits of *Gambusia affinis affinis*, with special Reference to the Malaria Mosquito, *Anopheles quadrimaculatus*. Amer. Jour. Hyg. **35**(1):142-151, 2 figs., 2 graphs, 5 refs. As the effectiveness of a predator in reducing the numbers of a species depends mainly on its biotic potential and the preference that it shows for the prey, and the rapidity with which *Gambusia affinis* has become abundant in the newly impounded waters of the Tennessee Valley indicates a satisfactory biotic potential, studies were carried out from 12th June to 20th September 1940 to determine whether it showed a preference for Anopheles.

The following is based on the authors' summary. Three different ecological situations in Wheeler Reservoir, Alabama, were included in the investigations, and they involved the collection and examination of 295 sq. ft. samples of surface organisms and the stomach contents of 1,018 *Gambusia affinis*. The forage ratio, obtained by dividing the percentage of a given organism in the stomachs by the percentage of it in the environment, was used as a criterion of feeding preference. The data obtained indicate that the size of the forage ratio for any particular organism is affected by the species composition of the population of food organisms, the relative and absolute densities of the organisms, and their stage development. Probably other factors, such as the amount of protection available for the prey, are also important. The size of the forage ratio for both Anophelines and Culicines was directly correlated with their population densities, but when they were present in equal numbers, the great preference was shown for Culicines. As mosquito densities increased, the number of fish eating them and the number eaten per fish also increased. The forage ratio for Anopheles was 1 when the larval density was about 2 per sq. ft. of water surface; below this point it decreased and above it increased, reaching over 14 when the larval density was 17 per sq. ft. Male Gambusia ate only half as much food as females of the same size groups, but it was of similar species composition. The amount of food eaten by females increased with their size, and the food of the largest fish contained a higher percentage of macroscopic food of all the fish, but they made up a higher percentage of the total food of larger ones, because the latter ate less plankton. In the case of all Diptera, Gambusia showed a much greater preference for pupae than for larvae, and for the later larval instars than for the early ones. In general, the studies indicated that availability is more important than choice in determining the extent to which a particular kind of organism will be taken as food by Gambusia.

124.* HILDEBRAND, S. F. 1919—Fishes in Relation to Mosquito Control in Ponds. U. S. Public Health Repts. **34**(21):1113-1128, 6 plates, 3 figs. Investigations as to the importance of fishes as eradicators of mosquito larvae are described. The observations were chiefly directed to determine the value of the top-minnow, *Gambusia affinis*. Nearly all the ponds in Augusta, which is the country under consideration, are artificial with sloping shores covered with aquatic vegetation. The newer ponds have steep banks.

All observations show that *Gambusia affinis* should prove a great asset in mosquito control. Wherever it was introduced, the mosquito larvae were exterminated in a very short time, unless sufficient protection was offered by submerged leaves or stems of plants.

During these experiments details of which are given, it was noticed that mosquitoes may breed in water so strongly acid that it will instantly kill Gambusia. The number of fish required to effect mosquito control in a given pond varies with the conditions being appreciably small where the water is free from aquatic vegetation and other hiding places for the larvae. The plants that afford most protection, and should therefore be removed, are an aquatic grass, *Hydrochloa caroliniensis*, a species of Myriophyllum (coon-tail moss) and algae. The latter may be sprayed with oil sufficient to make the masses of them uninhabitable by larvae without killing the fish. Although top-minnows are very prolific and multiply rapidly, to ensure their use in mosquito control they must be protected from predaceous enemies such as the large-mouth black bass. For this purpose shallow hiding places must be provided near water's edge.

Other fish that might prove useful in mosquito control include the star-headed minnow, *Fundulus nottii*, several species of sunfishes, the roach minnow and the gold-fish, the last-named being chiefly suitable for small and artificial waters.

125.* HILDEBRAND, S. F. 1921—Top Minnows in Relation to Malaria Control, with Notes on their Habits and Distribution. Public Health Bull. **114**:34. (Spanish translation in Bull. Pan American Union, Spec. Ed. Nov. 1922; Portuguese translations in Portuguese Ed., Dec. 1922). The fish dealt with are *Gambusia affinis*, *Heterandria formosa*, *Fundulus notti*, *F. notatus*, and *Mollienesia latipinna*. With the exception of the last named, all of these are of more or less value in eradicating mosquito larvae and pupae in the southern United States. The use of *Gambusia affinis* during anti-malaria campaigns in 1920 reduced the cost and added greatly to the permanent nature of the work. An account is given of the distribution and habits of this fish. In the case of *G. affinis*, new broods consisting of any number up to 200 are produced at intervals of 3 to 6 weeks throughout the breeding season, which varies according to the duration of the warm weather.

Owing to the limited observations made on *H. formosa* no definite information has been obtained regarding its relative value as an agent for the control of malaria, though it appears to be a serious enemy of immature mosquitoes.

The two species of Fundulus are probably of very limited importance; they are nowhere found abundantly, and seem to be difficult to propagate in large numbers, so that it is extremely doubtful whether it would be practicable to use them except under very restricted conditions.

126.* HILDEBRAND, S. F. 1921—Suggestions for a Broader Application of Gambusia for the Purpose of Mosquito Control in the South. Pub. Health Repts. **36**(25): 1460-1461. The value of the fish Gambusia in mosquito control is discussed, and its distribution to all standing and sluggish waters, so far as possible, is suggested. Ponds that are easily accessible and adapted to the propagation of the fish should be used to breed them for general distribution. Every effort should be made to educate the public as to the importance of this fish and where a supply of it may be obtained free.

127.* HILDEBRAND, S. F. 1922—Fishes as Guardians of Health. Outlook **130**, Mar. 22, 1922. An excellent account of the biology of *Gambusia affinis* and the effectiveness of that fish as a mosquito eradicator.

128.* HILDEBRAND, S. F. 1922—Fishes in Relation to Mosquito Control. Jour. Elisha Mitchell Sci. Soc. **37**(3 & 4):161-166. A general discussion on the feeding habits of fishes placed in artificial containers as to their activities in natural habitats. Experiments and observations relative to *Mollienisia latipinna*, a minnow structurally rather close to *Gambusia affinis* and usually found with the latter in great abundance in potential mosquito breeding areas, have led to the conclusions that the food of this species, *M. latipinna*, consists wholly of plants and that it is worthless as an agent for the control of mosquito production.

The author discusses the biology of *Gambusia affinis* and its effectiveness as a mosquito larvacidal agent in comparison with *Heterandria formosa* and species of the genus Fundulus.

129.* HILDEBRAND, S. F. 1925—Installation of Ponds for Propagating Gambusia at Impounded Water Projects. Public Health Bull. **156**:98-103.

130.* HILDEBRAND, S. F. 1925—A Study of the Top minnow, *Gambusia holbrooki* in its Relation to Mosquito Control. Public Health Bull. **153**: 136 pp. Investigations were conducted in Georgia during the summer of 1921 to 1924 with a view to obtaining accurate information on the actual value against mosquito larvae, under the widest range of conditions available, of *Gambusia holbrooki*, which is the species of top-minnow in the Atlantic Slope Region. They showed that an average total reduction of 51.8 per cent in the case of Anophelines and 80.8 percent in the case of Culicines may be brought about by the introduction of the fish into ponds or swamps constituting mosquito breeding grounds.

The most successful control by Gambusia was obtained by introducing the fish into an artificial pond that had previously contained no top-minnow and had a bottom growth of Myriophyllum, which was later superseded by Utricularia. Here the average reduction compared with 1921 over the three succeeding years was 97 per cent for Culicines and 75 per cent for Anophelines, the heaviest decrease occurring among pupae and large larvae. Similar treatment of various temporary swamps was less successful owing to the protection afforded to the larvae by vegetation, though a considerable reduction took place. Although complete control was not secured by introducing additional minnows into ponds already stocked with the fish, the reduction affected was large enough to be significant. It appeared from the experiments that Culicine breeding decreases more rapidly in cool weather and toward autumn than Anopheline breeding, and the Culicines in general are less successful than Anophelines in escaping the minnow.

A series of experiments was carried out to determine the degree of protection against Gambusia afforded by various types of vegetation. Observations in pond areas entirely cleared of vegetation showed complete absence of mosquito larvae until vegetation reappeared even when Gambusia was not present. *Hydrochloa carolinensis* is the most important plant of a protective type. Scattered growths of this grass were observed to harbor more larvae and pupae than dense ones, so that better control by Gambusia is secured by leaving them undisturbed.

The minnows were found to be effective in controlling Culicines and Anophelines in ponds where pine needle floatage had been deposited. The latter provided inadequate protection for mosquito larvae owing to the short time it remained afloat. In a ditch polluted by sewage water that had been treated with a commercial disinfectant as a larvicide, mosquito breeding continued but the fish died, although when oil was used instead of the disinfectant, the fish survived and controlled the mosquito larvae.

An increase in the water level brought about by heavy rains sufficient to submerge all vegetation resulted in almost complete elimination of mosquito breeding until readjustment took place. Where the vegetation was only partly submerged by rain, concentration round the remaining water-plants occurred, though it is probable that the total number of larvae and pupae acually present was smaller, particularly as the minnows are exceptionally active after rain. A constant water-level is thus conducive to maximum mosquito breeding both in fishless areas and in those stocked with Gambusia.

131.* HILDEBRAND, S. F. 1931—Gambusia in Foreign Lands. Science **74**:655-656. An account of the introduction and successfulness in the establishing of Gambusia into foreign lands. In Spain Gambusia established itself rather quickly. It is understood that Gambusia has been distributed, from the original introduction into Spain, to nearly all countries of Europe from Germany and Austria southward. The results claimed for Gambusia in southern Europe, and especially in Italy, as an eradicator of mosquito larvae far exceed those secured in United States. Gambusia has been introduced, not only into southern Europe, but also into Palestine (where it failed), the Philippine Islands (from whence it is reported to have reached China and Japan), the Hawaiian Islands, West Indies and Argentine.

132. HODGSON, E. C. 1914—Malaria in the New Province of Delhi. Ind. Journ. Med. Res. Simla **2**(2):405-415. Useful species of larvicidal fish are *Trichogaster fasciatus*, *Barbus phutunio*, *Nuria danrica* and *Aphiocephalus punctatus*.

133.* HOLLAND, E. A. 1933—An Experiment in the Control of Malaria in New Ireland by Distribution of *Gambusia affinis*. Trans. R. Soc. Trop. Med. Hyg. **26**(6): 529-538, 1 map. In New Ireland, Bismarck Archipelago, the geography, topography and climate of which are discussed, the only Anophelines found are *Anopheles punctulatus* Don., which usually breeds in clear water, and *A. punctulatus* var. *moluccensis* Sw. and Sw. de G., which is present in clean and dirty water, both being important vectors of malaria. At Kavieng, about 100 individuals of *Gambusia affinis* were introduced from Rabaul. Multiplication took place immediately in the drains, and the number of mosquitoes was diminished in a few weeks. The ponds, however, required restocking from the drains before breeding could be controlled. *Aedes aegypti* L. and *A. scutellaris* Wlk. which were also abundant, were quickly dealt with in tanks, guttering and other domestic waters.

134. HOPKINS, G. H. E. 1942—Modern Methods for the Control of Mosquitoes and Malaria. E. Afr. Agric. Jour. **7**(4):212-219; **8**(1):42-46. Introduction of larvivorous fish, such as Gambusia and Lebistes. Results not cited.

135. HOULE, E. C. 1922—Yellow fever, fifth zone, northwest coast of Mexico, 1919-1922. 13 pp. (Typewritten). The use of the indigenous fish *Rabalo plateado*.

136. HOWARD, H. H. 1920—Use of Top-Minnow (*Gambusia affinis*) as an Agent in Mosquito Control. International Health Board Rept. No. 7486, June 1920. 89 pp., New York. (Mimeographed).

137.* HOWARD, L. O. 1901—Mosquitoes. In his Natural Enemies of the Mosquito, pp. 156-166. New York. The use of fish, generally perch, in open shallow wells to keep down the mosquitoes and purify the water. Experiments on the indigenous fish of N. America.

138. HOWARD, L. O.—Preventive and remedial work against mosquitoes. Government Printing Office, 125 pp., Washington, D. C. (U. S. Bureau Ent. Bull. **88**). Use of fish in Panama.

139.* HOWARD, L. O. 1917—Remedies and Preventives Against Mosquitoes. U. S. Dept. of Agric., Farmers' Bull. **444**: 15 pp. Control by means of natural enemies is of practical value, one of the most useful being a gold-fish of the genus Girardinus which destroys the larvae, as do also some aquatic insects, while others as well as birds and bats eat the adults.

140.* HOWARD, L. O. 1923—Recent Results of Anti-mosquito Work of the Bureau of Entomology, United States Dept. of Agriculture. Proc. 9th Ann. Meeting N. J. Mosquito Exterm. Assoc., 1922, pp. 68-78, 8 figs., 1 map, Trenton, N. J. (New Brunswick, N. J.) An abstract is given of a report by Dr. D. L. Van Dine on impounding water in a bayou in Louisiana to control the breeding of Anophelines. A survey of *Gambusia affinis*, found in connection with the general breeding of Anopheles, shows that it finds no difficulty in establishing itself under conditions of relatively deep and open water. In the open water in the impounded area, however, there is no mosquito breeding, and the larger fish are present there in numbers and are an indirect aid to mosquito control, as the fact that they are predacious on Gambusia tends to drive the latter into the shallow water along the margins.

141.* HUBBS, CARL I. 1919—The Stickleback: A Fish Eminently Fitted by Nature as a Mosquito Destroyer. Calif. Fish and Game. **5**(1): pp. 21-24. The author presents the following points about the use of *Gasterosteus aculeatus*. The stickleback uses mosquitoes as food and the abundance of other foods will not deter the fishes feeding habits on wrigglers. The fish feeds at all levels of the water and seems rather immune to the attacks of larger fishes. The stickleback is a widely distributed fish, living in brackish bays to small mountain streams and pools. Summer temperatures seem not to effect *Gasterosteus aculeatus*. The stickleback is a hardy little fish and will stand transportation from its native streams to artificial ponds, in open buckets or in cans, such as those used to transport fish fry for planting in streams distant from the hatcheries.

142. INDIAN SYMPOSIUM OF MALARIA.—1938 Proc. Nat. Inst. Sci. India **4**(2):119-251, 1 map, 3 figs., many refs. In observations on the nutrition of *Panchax panchax*, S. L. Hora and K. K. Nair give account of experiments in the field and laboratory on the food of this top-minnow. They conclude that it is more effective in destroying mosquito larvae under Indian conditions than is Gambusia or Lebistes. The genus comprises of small, carnivorous surface-feeding fish that are exceptionally hardy, since they have been found to tolerate very foul waters and to live in damp situations out of water for long periods. They are reported to breed freely throughout the year in confined waters, to be difficult to catch and not to be valued as food. Thus they satisfy all the requirements laid down by malariologists for useful larvicidal fishes.

143.* JACKSON, L. E. 1927—Memorandum on Trials with Gambusia In Hudson County. Proc. 14th Ann. Mtg. N. J. Mosquito Exterm. Assoc., Atlantic City, 1927, pp. 84-86 (New Brunswick, N. J.). Tests with *Gambusia patruelis* and *G. affinis*, each of which gave practically the same results, showed that these fish have a decided preference for mosquito larvae, thrive equally well in salt and fresh water and are not disturbed by a rather high degree of pollution. They thrive best at a temperature of 73° F. in water containing some vegetation, a condition under which successful oiling is most difficult. Their preference for shallow water leads them to seek the inland ends of ditches, where mosquito breeding is heaviest, and prevents them from passing from the ditches into deep water from which they are not likely to return, thus rendering them suitable for salt marsh control. Although these fish are viviparous and are said to reproduce very rapidly where a high temperature is maintained, the breeding in New Jersey is likely to be short and no great increase in the number of fish imported could be expected there, while it is not yet certain that they will be able to survive the winter. Mosquito larvae remain absolutely still when aware of the approach of the fish, which rarely take one unless it is moving. The larvae shelter beneath vegetation or in the corners of a tank to escape detection.

144.* JENNINGS, A. H. 1912—Some problems of Mosquito Control in the Tropics. Jour. Econ. Ent. **5**:131-141. Use of fish in Panama.

145. JOB, T. J. 1940—Notes on the Geographical Distribution and larvicidal propensities of *Horachthys setnai* Kulkarm. Jour. Bombay Nat. Hist. Soc. **42**:201-202.

146. JOB, T. J. 1940—On the breeding and development of Indian mosquito-fish of the genera Aplocheilus. Rec. Ind. Mus. **42**:51-79.

147.* JOB, T. J. 1941—On the Comparative Efficacy and Relative Cost of biological and chemical methods of Mosquito Control in Clean-weeded Railway Borrow-pits at Fuleshwar, Bengal.. Jour. Malar. Inst. India **4**(2):211-215, 8 refs. A railway borrow-pit was divided into three sections, each 20 ft. by 12 ft., of which the first was dusted with 4 oz. of 2 percent Paris green mixture every fifth day according to the routine procedure in the neighboring area, the second was stocked with 96 adults and 48 young individuals of *Aplocheilus panchax*, and the third was left as an untreated control. The Paris green only destroyed Anopheline larvae in the late instars. Other stages of Anophelines and all Culicines being unaffected. The fish destroyed first the older larvae and pupae of both Anophelines and Culicines and later the younger larvae; the section was free of larvae and pupae four days after the introduction of the fish and remained so. All aquatic stages of mosquitoes continued to thrive in the control section. Excluding expenditure on supervising staff, which is essential in chemical control, the cost of treatment with Paris green was more than 20 times that of introducing the fish.

148. JOB, T. J. 1941—Efficiency of the Killifish, *Aplocheilus panchax* (Hamilton) in the control of Mosquitoes. Proc. Nat. Inst. Sci. India **7**:317-350.

149.* JORDAN, D. S. 1927—The Mosquito Fish (Gambusia) and its Relation to Malaria. Rept. Smithsonian Instn., 1926, pp. 361-368, Washington, D. C. The author advocates the introduction of Gambusia into countries infested with mosquitoes. *G. patruelis* and *G. holbrooki* devour eggs, larvae and adult mosquitoes in enormous numbers. They are prolific breeders, are easily transported and are capable of withstanding a large range of temperature. They have been found to survive in a pond covered with 1½ ft. of ice in Illinois, and have been observed in water at 102° F. In establishing

the fish in a new region, it is advisable to prepare a pond, not more than 4 ft. deep with a lining of concrete. Copper sulphate, sometimes used to clear the water in ponds, is fatal to Gambusia, and the large water beetle Dytiscus sp. is very destructive to it.

150.* JORDAN, J. 1937—Mosquito Larvicidal Measures. Chin. Med. Jour. **51**(6): 927-936, 4 refs. The value of larvivorous fish appears to be limited in Shanghai. Gambusia requires feeding during the winter months if necessity for re-stocking the ponds is to be avoided.

151. KALANADZE, L. AND I. MCHELIDZE. 1930—Data on the Biology of *Gambusia affinis*. Nachr. trop. Med. **3**(1):23-40, refs. Observations were carried out in and near Batum on the biology of *Gambusia affinis*, which, since its introduction into Abkhasia in 1924, has greatly increased in numbers and now plays an important part in the control of mosquitoes. It was found that the fish could survive under very unfavorable conditions; they thrived in highly polluted water which was hardly deep enough to cover them, and developed normally in water rich in tannin. The presence of any iron oxide in the water, however, was fatal to them, and when placed in sea water they died within a week. The young fish could subsist entirely on the micro-organisms that occurred in water containing vegetation. Other small fish were readily attacked by Gambusia even when mosquito larvae were available. Each female produced 50-100 completely developed young at a time, but under artificial conditions these were invariably devoured by the adult fish. In an experiment the young were dissected from the female and released in a separate reservoir, where they thrived normally. This method, is, therefore, recommended for breeding *G. affinis* under artificial conditions. In nature the young fish avoid being eaten by hiding among dense vegetation or by remaining in very shallow water. They feed on mosquito larvae of the first and second instars, and on various micro-organisms. The adults showed a definite preference for larvae of Culex, especially in reservoirs with abundant vegetation, and the eggs of Anopheles. One individual may devour 300 or more larvae in 5 minutes. At temperatures below 10° C. (50° F.) the fish hibernate in the mud.

Oiling was fatal to Gambusia only when applied in very shallow water devoid of vegetation, but most of the fish were killed by the usual application of Paris green.

152. KALANDADZE, L. AND I. MCHELIDZE. 1932—Materialien zur Biologie des Fisches Gambusia (Data on the Biology of Gambusia). Arch. Schiffs-u. Tropenhyg. **36**(10):539-544. The results of an experiment show that Gambusia can develop normally in water containing iron oxide.

153.* KALANDADZE, L. AND I. MCHELIDZE. 1934—Sur l'historie de la repartition des Gambusia et sur ses ennemis. (In Russian). Med. Parasitol. **3**(4):336-339, 9 refs. Notes are given on the history of the introduction of Gambusia into Europe and its establishment in the Russian Union.

154. KARAMANA, S. 1924—Les Anopheles en Macedoine et les measures a prendre contre eux. Glasnik (Bull. du Minist. de l'Hygiene) Belgrade. As regards prophylaxis, use might be made of the fish *Rhodeus amarus* of Lake Dorian and *Paraphoxinus minutus* and *P. epiroticus* of Lake Prespa and Ochrida. These species destroy all the larvae along the shores of these lakes.

155. KENNEDY, A. F. 1913—Fish in Drains and Swamps in Bathurst. Ann. Rept. Gambia Med. Dept., pp. 20-21, London. The Medical Officer of Health reports that during 1913 pools of water very rapidly dried up. The main drains swarmed with fish, which, for a day or two after heavy rains, ascended tributary streams for short distances and were found isolated in the upper reaches of these. In one main street-drain fish are found towards the sea-end and even in the dry season, and these are transferred as required to other drains, private wells, etc. Private individuals are having their wells stocked with fish and this has been found to be a better prophylactic measure against the breeding of mosquitoes than well-covers. Fish from the sea introduced into comparatively fresh water, take some time adapting themselves to it, but revive after a day or two and destroy larvae with avidity. The following figures are given with regard to one particular drain which had been dry for some time and filled up to 90 yards from the sluice gate during high tide in April, the average depth being 4 inches. On 23rd April,

the larvae present, half-grown or larger, were estimated to number 2,100. Eleven fish, six of 4 inch length and five of 2 inch, which had been kept for some time in a tub of fresh water, were introduced at 11 A. M. on this date and at 9 A. M. the following morning not a single larva could be found. Three fish about 1½ inches long were put into a bath of well water on the 29th October and on the 30th full-grown larvae were introduced at intervals of about 5 minutes as follows: 12, 13, 25, 30, 30. In 20 minutes, all these larvae with the exception of seven had been eaten and 2 hours later all had disappeared. On the 31st October two of these fish consumed thirty larvae in 3 minutes. Details of numerous experiments are also given, all tending to show that if the fish are properly treated, their capacity for destroying mosquito larvae is very great.

156.* KENNEDY, C. H. 1916—A Possible Enemy of the Mosquito. Mthly. Bull. Calif. State Board Health **12**(5):256-259. *Cyprinodon macularius*, a small minnow abundant in shallow pools and ditches in California, may prove useful in the control of mosquitoes, its food being minute aquatic insects and Dipterous larvae, especially of Chironomids. At the time of the author's investigations, it was too late in the season for mosquitoes to be present. Minnows of other species have been introduced with considerable success into Hawaii to combat mosquitoes.

157.* KHALIL, M. 1930—Introduction du poisson *Gambusia affinis* en Egypte, dans le Soudan anglo-egyptien, a Chrype et en Syrie pour combattre le paludisme. Ann. Parasit. hum. comp. **8**(6):593-597. The author describes the introduction of *Gambusia affinis* from Corsica into Egypt for the purpose of controlling malaria mosquitoes. This fish is more valuable than *Tipapia nilotica*, which lives in fresh water, and *Cyprinodon* sp., which lives in salt water. It multiplies rapidly in Egypt, where it has been widely distributed and it is particularly successful in covered collections of water. From Egypt consignments of the fish have been sent to Cyprus, the Sudan and Syria.

158.* KHAW, O. K. AND H. C. KAN. 1934—Some Observations on the Prevalence of Malaria in Nanking and its Vicinity. Chin. Med. Jour. **48**(2):109-123, 2 figs., 28 refs. Introduction of Gambusia into wells and pools.

159. KING, A. 1913—Report of the Medical Officer of the Second Division for the Year 1912-1913. Ann. Rept. on the Hospitals and Dispensaries, St. Lucia, Castries. Malaria and pellagra are mentioned among the diseases prevailing in the district the past year, although preventive measures were still carried out in a small way by distributing "Millions" fish in pools, cleaning edges of streams where vegetation might harbor Anopheles larvæ, distributing quinine in schools, etc. The conditions during most of the year were not favorable for the "Millions," as there were many spells of dry weather, during which they all died, except in large collections of water. The smaller pools required constant re-stocking.

160.* KLIGLER, ISRAEL J. 1930—The Epidemiology and Control of Malaria in Palestine. Biological Methods, pp. 152-154, University of Chicago Press, Chicago. We have succeeded in acclimating Gambusia brought from the United States, and have also experimented with the native Cyprinodon and Tilapia. The native Cyprinodons do not feed on other food besides larvae. They are not top feeders, and rarely hunt their food among surface plankton. When confined in small clean pools or aquaria, they will keep them free from culices or anopheles. In pools covered with algae or surface vegetation, they are practically useless.

With Gambusia we have had more satisfactory experience. Their usefulness as larvae destroyers under local conditions where vegetation is abundant and the microfauna rich enough to supply their needs without great trouble, is limited. In moderately clean canals, on the other hand, or in pools having limited food supply, they yield excellent results.

In observing the various small fish, it was noted that the Tilapia are omnivorous feeders. Under confined conditions in the laboratory, they eat algae, vegetable matter, such as leaves and young shoots, larvae, and young Cyprinodons or Gambusia with equal voraciousness. This fish breeds in most of the streams of the country, grows to the size of the perch, and is a good eating fish. The first experiments were not reassuring, but as soon as the numbers grew, the results were excellent. It is apparently a question

of balance between the number of fish and the rate of growth of the algae. When there are forty or fifty fish per tank, it remains permanently clean. At times it was found that the grove-owners even added food (bread).

161.* KULAGIN, S. M. AND V. I. MARTZINOVSKII. 1936—Essae d'acclimatation des Gambusia dans les etangs refrigerants d'une centrale electrique (In Russian). Med. Parasitol. **5**(1):52-61, 1 diagr., 28 refs. (With a summary in French). In the autumn of 1935, fish from the breeding ponds were sent to several anti-malaria stations in the Department of Moscow and liberated in natural accumulations of water. Previous attempts to establish Gambusia in the Moscow region have shown that they thrive under natural conditions and are effective against Anopheline larvae.

162.* LEGENDRE, JEAN. 1913—Prophylaxie du paludisme en Italie. Bull. Soc. Path. exotique **6**:468-476. Terni, of Italy, examined the stomach contents of small tenches (*Cyprinus carpio*) and in each found from sixty to eighty mosquito larvae.

163. LEGENDRE, J. 1916—(Destruction of Mosquitoes by fish). C. R. Hebcom, Acad. Sci., Paris **163**(15):377-378.

164. LEGENDRE, J. 1920—Les poissons d'Ornement et Mangeurs de mostiques dans les Aquariums et les pieces d'eau. Rev. Hortic. de l'Algerie, **24**(1-2):32-34.

165.* LEGENDRE, J. 1927—Poissons larvivores de la Haute-Volta. Technique de l'emploi des poissons contres les maladies a moustique. Bull. Soc. Path. exotique **20**(6): 476-480, 18 refs. The importance of fish in the destruction of mosquito larvae is pointed out. *Clarias lazera, Schilbe mystus* and *Tilapia nilotica* have been used in the Upper Volta for the control of mosquitoes breeding in small collections of water with satisfactory results. The method of handling the fish is briefly discussed.

166. LEGENDRE, J. 1928—Poissons culicivors—leur emploi. Rev. Hist. nat. app. (1) **9**(5):138-140. This is a popular account of the use of fish against mosquito larvae, the author pointing out that there are many cases in which the method is effective. Mosquito larvae in water-butts and ponds in gardens are destroyed by gold-fish, and larvivorous fish can also be used in wells that provide water for animals, although they should not be placed in wells that provide water for human consumption. The author found an eel to be ineffective in destroying Culicine larvae in a well. Fish are also valuable for preventing mosquito breeding in pools left in the beds of rivers that dry up in summer; in such cases fishing in these pools should be prohibited, and fish should be introduced if not already present.

167. LEGENDRE, F. 1934—Introduction of Gambusia into Madagascar. Bull. Soc. Path. exotique **27**:291-294.

168.* LEMASSON, J. 1937—L'utilisation de *Gambusia affinis* et *Girardinus guppyi* pour la luttu antimalarienne. Bull. econ. Indochine **40**(2):328-330. The desirability of attempting to establish *Gambusia affinis* and *Lebistes reticulatus* (*Girardinus guppyi*) for the control of Anopheline larvae in Indo-China is questioned. A number of examples of Gambusia introduced into ponds in Tonkin bred prolifically between March 1935 and March 1936, and then disappeared completely. Others introduced into a pond in Cochin, China increased enormously in numbers between April 1936 and March 1937. If the disappearance of the fish in the first case was due to the unsuitability of biological or ecological conditions, then the fish would have to be specially reared and the expenses incurred would be great. On the other hand, although the climate in Cochin and Cambodia would appear to be favorable, it is feared that the introduced fish would destroy large numbers of the indigenous varieties that not only form one of the staple articles of food of the natives but are also dried and exported in large quantities. These arguments apply equally well to both species. It is concluded that since the utilization of larvivorous fish is, at best, only supplementary measure against malaria, it is undesirable to introduce the exotic species, particularly as there are several widely distributed native species that are not only equally larvivorous but are also of considerable food value.

169.* LENERT, L. G. AND E. STUART. 1926—Report of Division of Malaria Control. 29th Bienn. Rept. Calif. State Board of Health, 1924-1926, pp. 82-85. Sacramen-

to, California. This is a brief summary of the activities of the Division of Malaria Control during 1924-1926 in the various counties of California. The work has consisted chiefly of surveys with a view to anti-malarial measures and the distribution of the fish *Gambusia affinis*.

170.* LE PRINCE, J. A. 1922—Fish as an Anti-mosquito Agency. Southern Med. Jour. **15**(5):371-374. Most of the malaria in the southern United States is due to *Anopheles quadrimaculatus*. The top-minnow, *Gambusia affinis*, is best suited to the waters in which this mosquito breeds, and is, generally speaking, limited to the malaria belt. It is a powerful agent in destroying *A. quadrimaculatus*.

171.* LE PRINCE, J. A. AND A. J. ORENSTEIN. 1916—The use of fish in mosquito control. Mosquito Control in Panama, pp. 180-185, New York. The successful use of Gambusia and other minnows abound in brooks and ditches in Canal Zone.

172.* LE VAN, J. H. 1941—Methods for Controlling *Aedes aegypti* Mosquito with *Gambusia holbrooki* Minnows at Key West, Florida. Public Health Rept. **56**(23): 1217-1221, 2 pls., 6 refs. An account is given of the introduction of *Gambusia holbrooki* into cisterns and wells in Key West, Florida, for the control of *Aedes aegypti* L. A careful inspection of 2,376 containers in May and June 1940, rather more than a year after they had been stocked, revealed the presence of fish in 1,105 of them, and mosquito larvae were found in only eight of these. Fish were found in roughly half of the cisterns inspected. Many of those from which they were absent had been pumped dry and had not been restocked when refilled. Mosquito larvae were found in 392 of the 869 cisterns, 216 of the 332 wells, and 24 of the 70 barrels in which there were no fish.

173. LLOYD, R. E. 1910—Mosquitoes and Fish. Jour. Bombay Nat. Hist. Soc. **20**:1165-1166. The author states in a short note referred to the supposed value of the "Millions" for reducing malaria in Bardalos and in this connection remarked that a natural balance exists between the numbers of any species and the amount of food that is available for their nutrition. He referred to the investigations with Haplocheilus (*Panchax panchax*) in Bengal as a larvicidal form, and from his own observations in the Zoological Gardens at Alipore, Calcutta, he concluded that the species was not so efficient for larvicidal campaigns, as had been affirmed by other workers.

174.* LOFTIN, U. C. 1919—Mosquitoes found about Gainesville, Florida. Mosquitoes and Disease. Florida Buggist **3**(3):37-43, 48-50. The relation between mosquitoes and such diseases as malaria and yellow fever are discussed. The most active enemies of mosquitoes in Florida are the minnows, *Gambusia affinis* and *Chaenobryttus gulosus*. The usual remedial measures against both adult and larval mosquitoes are reviewed and recent drainage operations in various states are described.

175.* LOWRY, R. P. 1929—Mosquitoes of New Hampshire. A preliminary Report. New Hampshire Agric. Expt. Sta. **243**: 23 pp., 1 pl. The most important natural enemy of the salt mosquito in New Hampshire is the killfish, *Fundulus heteroclitus*, which is extremely abundant and follows the incoming tide anywhere on a marsh where there is sufficient water. Mosquitoes can only breed successfully in isolated pools that are not reached by ordinary tides.

176. MACDONALD, W. R. 1914—A Short Note on the Use of Larvicidal Fish in Combating Malaria Fever. Proc. Third All-India Sanitary Conf. **4**:75-77. The larvicidal fish usually met with in Madras City are *Haplochilus panchax*, *H. melastigma*, *H. lineolatus*, *Chela* sp., *Rasboro daniconius* (common minnow), and *Therapon jarbua*, in brackish water. Haplochilus is very voracious, and Chela and Rasbora also kill many larvae, while *Therapon jarbua*, though very efficient, is not so widely distributed. A large number of wells and tanks were stocked with fish, but these at first made no headway against the larvae, which were apparently too numerous for them. Several tanks close to the Tamil Mission Orphanage, in which all the inmates were sick with intermittent fever, were found to contain quantities of fish, and at the same time to be swarming with larvae. The water was, however, covered with a mass of algae, in which the fish and larvae were entangled. The building swarmed with Anopheles in February, as did also the dense jungle around. The larvae were found to be those of *A. ludlowi*,

A. fuliginosus, *A. jamesi* and *A. barbirostris*, and could be obtained in practically any numbers. The weeds were removed, the margins trimmed and made smooth so as to destroy all pools and footprints. The water was covered with petroleum, which did not in any way interfere with the fish, and by the end of March, the mosquitoes had diminished and the health of the occupants improved. By June there were no cases of fever and no larvae.

177.* MACGREGOR, M. E. 1920—The question of natural enemies. Jour. Trop. Med. **5**(23):145-146. A study of the balance between the number of fish that a certain volume of water can support and the amount of food available.

178. MACGREGOR, M. E. 1924—Report on the Anopheline of Mauritius, and on certain aspects of Malaria in the Colony, with Recommendations for a new anti-malaria campaign. 48 pp., 2 pls., 33 figs., 4 maps. London. Though larvivorous fish are very abundant and widely distributed, they are not of any great value under natural conditions, but in artificial waters their use has proved very successful.

179.* MALARIA COMMISSION OF SPAIN. 1926—Brit. Med. Jour. **3442**: p. 1237. Best results have been obtained from the use of the fish Gambusia, which was introduced from the United States in 1921. This fish feeds freely on the larvae and seems to have become well acclimatized.

180. MARTINI, E. 1920—Über Stechmücken, besonders deren europäische Arten und ihre Bekämpfung. Beih. Arch. Schiffs-u. Tropenhyg. **24**:1-267. The following fish were used in mosquito control: *Cyprinodon calaritanus*, *Phoxenus laevis* and *Telestes muticellus*.

181.* MAZZA, S. AND C. GONZALES. 1926—Informe epidemiologico paludico de la margen izquierda del rio Chico en la cuidad de Jujuy. (Epidemological Report on Malaria on the left Bank of the Chico River in the City of Jujuy, Argentina). Biol. Inst. Clinica quirurg. Univ. Buenos Aires **2**(11):154-162, 5 figs. It is believed that a small fish, *Fitzroya leniata*, is the factor that prevents an increase of mosquito larvae in the river.

182.* MCCORMICK, E. M. 1940—The relation between the amount of Arsenic a fish gets from Mosquito-control Dusting and the Lethal Dose. Jour. Tenn. Acad. Sci. **15**(3):342-351, 5 refs. Details are given of experiments on the effect on fish, particularly Gambusia and a catfish, of dusting with Paris green against Anopheline larvae in the neighborhood of the Reelfoot Lake, Tennessee. There was no evidence that fish were killed. Those caught in nature showed the presence of arsenic on the body but not in the alimentary tract. Some of those exposed to Paris green in the laboratory died, but probably not from arsenical poisoning. Although a very small amount of arsenic was found in one batch of two alimentary tracts, and death in this case might possibly have been due to poisoning, no arsenic was found in the other fish that died, and the positive result may have been caused by the accidental inclusion of a part of the body in the test material. Moreover, other fish survived in water treated with much larger quantities of Paris green.

183.* MCHELIDZE, I. Z. 1930—The Control of *Aedes aegypti* in Batum. Trop. Med. Vet. **8**(10):26-27. The introductien of Gambusia resulted in a considerable decrease in the number of mosquitoes.

184. MESSEA, A. AND G. BRUNELLI. 1926—Istruzioni per l'impiego della Gambusia nella lotta antimalarica. (On the use of Gambusia as an Antimalaria Measure). 9 pp., 2 figs., Rome. An account is given of the top-minnow, Gambusia, and its use against mosquito larvae.

185. MISSIROLI, A. 1930—Prevention of malaria in practice (Ital.) Third Dept. (1928-29). Riv. Malariol. **9**(6):667-705. In Ostis, Gambusia replaced *Cyprinodon calaritanus* in three to four years.

186.* MOLLOY, D. M. 1924—Some Personal Experiences with Fish as an Anti-mosquito Agency in the Tropics. Amer. Jour. Trop. Med. **4**(2):175-194, 6 figs. The use of fish against mosquito larvae is reviewed, and the author's personal experience in

Nicaragua is described. *Poecilia sphenops*, a fish of great value in Nicaragua, is found throughout Central America both in tidal waters and mountain streams. It is hardy and stands transportation well.

During the yellow fever campaign in 1919 all wells and other artificial water containers were restocked with this and other fish, and the disease, which was already on the wane, disappeared. The malaria rate was also greatly reduced.

Among the chief factors to be considered in using fish for mosquito control are the number of fish present in a given area and amount of available food-supply. In the case of limited food-supply the fish will surmount almost any barrier such as vegetation to get at the most remote breeding place. Examples of this type of natural control existing in Nicaragua are described. By assisting the fish (brushing and cleaning the edges of the ponds and streams) mosquito control could be made almost absolute so far as artificial ponds and streams are concerned.

187.* MONROE, W. M. 1923—Notes on the Limit of the Usefulness of Fish in Larvae (*Aedes calopus*) Control. Amer. Jour. Trop. Med. **3**(1):21-26. For the control of *Aedes argenteus* (*calopus*) the use of fish in fresh water containers has proved most valuable. A number of experiments have been carried out to test the efficiency in this respect of the bottom feeders, *Dormitator maculatus*, and the top feeder, *Gambusia micaraguensis*. The results showed that the average consumption of mosquito larvae for these fish generally is about 150 a day, bottom-feeding fish being rather more efficient for their weight than top feeders. When breeding occurs in barrels where fish are present, it is due to the fact that the number of mosquito larvae is beyond the limit of the feeding capacity of the fish.

188.* MOORE, J. P. 1922—Use of fishes for control of Mosquitoes in northern fresh Waters of the United States. Appendix IV to the report of the United States Commissioner of Fisheries for 1922. U. S. Dept. Commerce, Bur. Fisheries, Document No. 923, 60 pp., Washington, D. C. No fish of which mosquitoes are more than an incidental item of diet have been found in the fresh-waters of the north-eastern United States but several species of small fish and the young of some larger ones native to these waters eat larvae, pupae and eggs of mosquitoes more or less habitually. Of these the most important are *Eupomotis gibbosus*, the most useful species of ponds and lakes; *Umbra pygmaea*, for shallow or swampy areas; and *Fundulus heteroclitus*, for fresh and brackish tidal marshes. *Gambusia affinis* has not survived the northern winters, but multiplies so rapidly that it may be used effectively against both Culicines and Anophelines in small ponds and water gardens by restocking each spring. Small goldfish are useful in fountain basins and small ponds with clean sides, and are preferable to the top minnow for use in rain-water tanks.

189.* MORIN, H. G. S. AND P. MARTIN. 1936—Utilisation des poissons contre les moustiques. Arch. Inst. Pasteur. Indochine **6**(24):443-505, 5 pls., 3 figs., 9 pp. refs. In the first paper of this series pp. 443-461, H. G. S. Morin and P. Martin review briefly the history of the use of fish for the control of Anopheline larvae in anti-malaria work, give lists of the fish that have been employed for this purpose in various countries, discuss the advantages and disadvantages of using indigenous species, quote examples of the practical application of the method in Java, and give notes on precautions that should be taken to ensure the survival of the fish during transportation and rearing.

The next two papers, by Morin (pp. 462-464) and by Morin and Martin (pp. 465-469), deal with experiments on the establishment in Indo-China of *Lebistes reticulatus* (*Girardinus guppyi*) and *Gambusia affinis*, respectively.

The fourth (pp. 470-471) is a list of the fish collected in Indo-China by the anti-malaria service of the Pasteur Institutes, showing the fish that feed on mosquito larvae in the laboratory. In the fifth (pp. 472-476), P. Chevey gives a key to the freshwater fish of Indo-China, and the sixth (pp. 476-484), he describes four that may be of value in the destruction of mosquito larvae. In the last paper (pp. 485-495) Morin and Moreau give a brief account of the research that has been carried out in the Pasteur Institutes in Indo-China on the utilization of indigenous and exotic species of fish. The

work has been of an experimental nature, and it is concluded that the problem should now be taken up by the piscicultural authorities, with a view to making tests on a large scale under natural conditions and developing methods for rearing the most suitable fish.

190.* M. R. 1920—Les Moustiques et les Canards. Jour. d'Agric. Pratique **33**(20): p. 364. An experiment is recorded in which two basins of equal size were made in a mosquito-infested stream, one being stocked with fish and the other with ducks. That containing fish continued to show mosquitoes in all stages, but after two days that containing ducks was freed from mosquito larvae and pupae. This confirms previous observations of the usefulness of ducks in mosquito suppression.

191.* MUFEL, P. P. AND E. M. GUTERMAN. 1937—Lutte contre les larves d'anopheles dans les etangs poissoneux. Med Parasitol. **6**(2):239-242, 2 refs. In view of the fact that fish die in water that has been oiled for the control of Anopheline larvae, experiments to study the effect on them of arsenical dust larvicides were carried out in the summer of 1936 in the Province of Voronezh. For this purpose, three large artificial water reservoirs containing dense aquatic vegetation and infested with Anopheline larvae were stocked with very young and one-year-old carp; the plants rising above the surface of the water were cut, and the water was repeatedly treated with dust shaken from a muslin net. In one dusted with Paris green mixed with oleogumbrin in the proportion of 1:20, the film that formed on the surface remained intact for several days, and the number of larvae was reduced from 4.7 to 0.0-0.004 per sq. meter. Another reservoir was dusted with a mixture of calcium arsenite, Paris green and oleogumbrin, which gave less than 50 per cent control and the third with calcium arsenite mixed with road dust (1:10), which reduced the number of larvae per sq. meter from 12.7 to 2.3. Analysis of the water before and after the treatments showed that there was no appreciable change in its composition, and no change occurred in the plankton and benthos. The condition of the fish was not affected in any way. This was confirmed in laboratory experiments in which young fish were placed in glass jars and the water was dusted with mixtures of oleogumbrin and calcium arsenite or Paris green. The films remained on the surface of the water for 5, 6 and 24 hours respectively, and the fish continued to be very active and in perfect condition. In another experiment, young fish and Anopheline larvae were kept in a wooden box in one of the artificial reservoirs so that it was half full of water. The fish were dissected 2-3 days after dusting and their digestive tracts analyzed for the presence of arsenic. The results were invariably negative. The fish were very active all the time, and the larvae were quickly destroyed by them.

192. MUHLENS, P. 1912—Ein grosserer Versuch der Muckenvertilgung in der Gemeinde Wohldorf-Ohlstedt bei Hamburg. Beih. Arch. Schiffs-und Tropenhyg. **16**:66-75. Shilling cites good results in the destruction of mosquitoes in the west side of Berlin. The effort consisted of fumigation in the winter and the introduction of small fish into ponds, and fountains in the gardens in the spring.

193.* MULLIGAN, H. W. AND S. A. MAJID. 1936—Some Notes on the Care, Transportation, and Use of *Gambusia affinis* under Indian Conditions. Rec. Malaria Surv. India **6**(4):537-547, 1 pl., 2 refs. In 1929, a stock of the top-feeding minnow, *Gambusia affinis*, was established at Karnal. Demands for supplies for use in Anopheline control work have increased to an enormous extent in recent years, and requests have been continually received for information on the care and use of the fish. The present paper has been prepared with a view to answering some of the commoner questions regarding their rearing, maintenance and transport under Indian conditions, and the types of mosquito breeding places in which they have proved most effective.

194. MURPHY, W. O. 1914—Larvae-eating Fish in India (M. S.). (Reference incomplete, title and abstract secured from Prashad and Hora "A general Review of the Probable Larvivorous Fishes of India," Rec. Malaria Surv. India **6**(4), Dec. 1936). Murphy during his extensive tours in Naivabashah, Hyderabad and parts of Karachi district in Sind investigated various indigenous fishes to test their larvae-eating propensities. He found that the smaller fish of the species, *Cirrhina mrigala*, *Ambassi ranga*, *Perilampus atpar* (*Laubuca atpar*), *Nuria danrica* (*Esomus danricus*), *Barbus terio* and *Gobius guiris* (*Glossogobius giuris*) were all useful as larvicidal forms. Some

other species which could not be identified, were also found to have larvivorous propensities. According to him, no mosquito larvae were found in any pool in which any of the five species of the fish listed above were present, and a decided preference was shown by the fishes for larvae rather than pupae.

195.* MYERS, G. S. 1925—Fishes and Human Disease. Fish Culturist **5**(4):27-29. The value of fish in mosquito control is briefly reviewed, with particular reference to Guayaquil, where the last remaining yellow fever mosquito (*Aedes argenteus* Poir) was exterminated by the use of *Lebiasina bimaculata*, *Dormitator latifrons* and *Lebistes reticulatus* in domestic water-containers. Species of Gambusia and *Panchax* (*Haplochilus*) *panchax* are very largely used wherever conditions are favorable, and apparently always with success. The bottom-feeding catfish, Astroblepus (Arges) of the Andes, is a ravenous mosquito feeder at night and has been used much in Peru. Species belonging to the genera Poeciliid and Rivulus seem to have been overlooked in this connection, common throughout tropical America, which is undoubtedly an important factor in mosquito control in the jungle, as it can travel overland and is found in every little mudhole and hoof-print and in the leaves of floating aquatic plants.

196.* MYERS, G. S. 1927—An Analysis of the Genera of Neotropical Killi-fishes allied to Rivulus. Ann. and Mag. Nat. Hist. (9) **19**(109):115-129. This is a systematic account of the fish of the Neotropical region belonging to the tribe Rivulini of the Poeciliid subfamily Fundulinae including descriptions of new genera and species. The fish destroys mosquito larvae.

197. ORPEN, R. W. 1917—Colony of the Gambia. Annals Med. and Sanit. Rept. for year 1916. 25 pp. Bathurst. Fish that are successful in wells, lagoons and aquaria include *Chromis bimaculatus* and *Hemichromis mecrocephalus*.

198. OSBORN, H. L. 1907—Destruction of Mosquitoes and their larvae by Fish and Lime. Jour. Bombay Nat. Hist. Soc. **17**:832-833. "Chilwai" (*Chela argentea*) was advocated as a very valuable larvicidal fish in view of the fact that the species is a surface-feeder and is easily procurable in most parts of India. The author conducted some experiments in a cistern about 8 to 9 feet long by 5 feet broad and 5 feet deep, and found that 50 to 60 "Chilwai" were able to clear the cistern of mosquito larvae within a week or so.

199. OXNER, —. 1930—Trois annees d'experiences d'acclimation des Gambusia sur la Cote d'Azur. Mesures antilarvaires dans la lutte generale contre les moustiques et instructions techniques sur l'emploi des poissons larvivores. 20 pp., Soc. Med. Litt. Mediterr., Nice. The history of the importation into Europe of Gambusia is reviewed with notes on the conditions favorable to the life, transport and reproduction of these minnows; and an account is given of the results of rearing and acclimatizing them during three years in the South of France, where they have reproduced in quantities and mosquito larvae are not found in water that they occupy.

For the liberation of Gambusia, it is possible either to release large numbers for immediate effect in small areas, preferably during the spring, or smaller numbers in order that they may increase during one season and become effective in the next. In the letter case, they should be liberated in early spring or better still in October. Every two years it is well to add a few pairs of different origin to each reservoir of water so as to prevent the stock degenerating.

200. PALADINO-BLANDINI, A. 1933—Ordinamento e primi risultati della lotta antianofelica generale in Calabria. (The Organization and first Results of general antimosquito Work in Calabria). Riv. Malariol. **12**(1):118-195, 30 figs. *Gambusia holbrooki* was introduced in 1928 to 1931. No results were cited.

201.* PANAGIA, A. 1932—Esperienze ed osservzioni sulla delarvizzazione anofelica nella profilassa malaria. (Experiments and Observations on Work against Anopheline Larvae in Malaria Prophylaxis). Riv. Malariol. **11**(4):453-467. Notes are given on the results of test of action of a variety of substances on Anopheline larvae, but the author concludes that in practice none of them would give results in control comparable with those obtainable with *Gambusia holbrooki*, Paris green, and oiling. Experiments by Dr.

W. Mundula in the author's laboratory in Rome showed that if large numbers of larvae were available, *G. holbrooki* would devour so many that their digestion entailed a prolonged fast during which other larvae developed undisturbed. This drawback could be remedied by regulating the proportion of fish to larvae. In water poor in vegetation *G. holbrooki* was found capable of destroying 60-80 per cent or more of the larvae.

202.* PARKER, GEORGE W. 1921—Fish Control. U. S. Public Health Bull. **115**: 39-41. It is Parker's opinion that Gambusia provides an effective mosquito control.

203.* PARKER, GEORGE W. 1922—*Gambusia affinis*, the Natural Agent for Destroying Mosquito-breeding in Texas. Texas State Jour. Med. **17**(12):579-581, 2 figs. The Texas State Board of Health has found *Gambusia affinis* a valuable auxiliary in Mosquito destruction. Data regarding the use of this fish are given.

204.* PEACH, J. H. 1923—Experiments made with larvivorous Fish in British Honduras. Jour. R. Sanit. Inst. **43**(7):335-336. The species of fish said to be larvivorous in British Honduras are *Tetragonopterus aeneus*, *Cichlasoma octofasciatum*, and *Mollienisia sphenops*. All of these fresh-water species are able to live in rain water with little light and no artificial feeding, and they appear to destroy mosquito larvae effectively.

205. PECORI, G. AND G. ESCALAR. 1930—Relazione sulla campagna antimalarica dell'anno 1929. (Report on the anti-malaria campaign in 1929 in the Government District of Rome). Riv. Malariol. **9**(5):479-549, 14 figs., 1 map, 2 diagr. In spite of distributing over 116,000 Gambusia, this fish could not be established in waters rich in carbonic acid. Trout proved to be of some value in the destruction of mosquito larvae.

206.* PECORI, G. AND G. ESCALOR. 1934—Relazione sulla campagna antimalarica nell'Agro Romano durante l'anno 1933. (Report on the antimalarial Campaign in the Area round Rome during 1933). Riv. Malariol. **13**(5):623-668, 1 map, 2 graphs. 78,500 Gambusia were placed in waters where this fish was rare or absent. The breeding of trout was continued on a property where their efficiency was proved by the absence of malaria since 1932.

207. PERYASSU, A. 1930—O emprego de peixes na destruicao das larvas de mosquitoes. (The Use of Fish in the Destruction of Mosquito Larvae). A Folha medica **11**(14):160-162, 2 figs. In this popular article on the use of fish against mosquito larvae, it is stated that *Astyanax rutilus* is very abundant around Rio de Janeiro, and is of considerable value in this connection.

208.* PETERSON, E. AND F. D. WALKER. 1923—Mosquito Control in St. Thomas. U. S. Naval Med. Bull. **18**(3):291-303, 7 figs. Of the various rural mosquitoes found in the Island of St. Thomas, West Indies, the only disease transmitter is *Anopheles albimanus* Weid. carrying malaria. *Aedes argenteus* Poir (*aegypti* L.) and *Culex fatigans* Weid. (*quinquefasciatus* Say) are practically the only species breeding in the town of St. Thomas. By means of a complete system of surface drains, the Danish authorities changed the aspect of the malaria problem from urban to more or less rural. In rural areas Anopheles larvae are kept down by fish, particularly by *Lebistes reticulatus*, introduced many years ago, but specially imported in 1919 from St. Kitts. For the past two years no cases of malaria have occurred. In town, the tubs in which mosquitoes breed may be covered with gauze or stocked with fish.

209.* PETRAGNANI, G. AND A. CASTELLI. 1927—Le Gambusie nella lotta antilarvale in provincia di Cagliari (con particolare reguardo alla biologia). (Larval Control by Means of Gambusia in the Province of Cagliari with special Notice of the Biology of this Fish). Riv. Malariol. **6**(4-5):709-727. *Gambusia holbrooki*, which was imported some years ago, is now established in Sardinia. It can live in water with a salt-content of 20-25 per mille as well as in fresh-water, and can live in waters too rich in decomposing organic matter for other fish, a fact that renders it useful against Culex. It is extremely prolific, but where suitable food is lacking, the young fish are eaten by the adults. At temperatures of 20-30° C. (68-86° F.) the fish lived without food for over three weeks. It is advisable to stock the salt-water pools communicating with canals and ditches, even if their salinity precludes the occurrence of mosquito larvae, because in the dry season, when the canals and ditches dry up the pools themselves remain as a nursery

for the fish, which can regain the canals when they are again filled. Each fish can keep a water surface of 11 sq. ft. free of larvae.

210.* PETRISHCHEVA, P. A. 1936—Die Rolle der Gambusien und einiger einheimischer insektenfressender Fiesche im Kampf mit der Malaria in Turkmenien. (The Role of Gambusia and some indigenous insectivorous Fish in the Control of Malaria in Turkmenistan). In Pavlovskii (E. N.) Animaux pathog., pp. 111-138, 13 figs., 35 refs., Moscow. Inst. Med. Expt. U.S.S.R. Gorki. A brief account is given of the use of different species of fish against mosquito larvae in the Russian Union since 1911, together with details of work in Turkmenistan in 1929 and has greatly increased in numbers and spread in a system of ponds and ditches that become connected at the time of spring floods. The types of water in which it breeds are discussed. The methods used for transporting Gambusia to different districts in Turkmenistan are described. Laboratory observations on the fecundity of the female showed that 6-7 broods of 60-80 young fish may be produced from April to the end of October. Of the native larvicidal fish, *Alburnoides bipunctatus eichwaldi, Varicorhinus heratensis* and *Nemachilus malapterurus* are the most important; notes are given on their habits and the types of water in which they thrive. In the laboratory Alburnoides destroyed more mosquito larvae in a given time than the others, but not so many as Gambusia; Varicorhinus destroyed more than Nemachilus. Suggestions are made for the extended utilization of these fish in Turkmenistan.

211. PHILIPPINE ISLANDS BUREAU OF SCIENCE 1916—(Use of Fish in Mosquito Control). In its Annual Report, 12th Manila, 1913, p. 67; 15th, Manila, 1916, p. 27. (Reference not complete, source of title, Rockefeller Foundation "Use of Fish for Mosquito Control," Rockefeller Foundation, Inter. Hlth. Bd., 10 Ann. Rept. 1923, pp. 80-93, New York.)

212.*PHILLIPS, W. J. 1930—Use of Fishes for Control of Mosquitoes. N. Z. Jour. Sci. Tech. **12**(1):19-20. The mosquito menace is not regarded as serious in New Zealand, where Anophelines have not yet become established, though in view of their possible introduction and also because of the discomfort arising from the attacks of indigenous Culicines, the mosquito-eating fish, Gambusia, is being imported. The success of this fish in other countries is briefly reviewed. There are five species of fish indigenous to New Zealand that are probable enemies of mosquitoes, though the only one in which mosquito larvae have actually been found is the smelt, (*Retropinna retropinna*).

213. PIERCE, W. D. 1918—Mosquito Control. Agric. News, Barbados **17**(433-434):374-375, 388-389. This article is a resume of modern knowledge of mosquito control by means of sanitary engineering works, larvicides, oiling and predatory fish. The protection of dwellings by screening and of the individual by repellants is dealt with, formulae for some of the recognized repellants being given.

214. PITTALUGA, G. 1918—A communication on the measures required to check malarial epidemics in Upper Aragon. Bol. Inst. Nac. Higiene, Alfonso XIII, Madrid **14**(54):103-116. *Ciprinus carpio* was successfully used in Spain.

215.* POMEROY, A. W. J. 1920—The prophylaxis of malaria in Dar-es-Salaam, East Africa. Jour. R. Army Med. Corps **35**(1):44-63. Dr. Spurrier tried imported fish from the Seychelles, but the local species have proved just as effective and there is a plentiful supply of them. The fish used in the campaign were all indigenous, consisting of *Tilapia nilotica, T. ovata, T. natalensis, T. mossambica, Ambassis commersonii Fundulus guntheri, Mugil macrolepis, Gobius giures* and *Eleotris fusca.*

216.* PRASHAD, B. AND S. L. HORA. 1936—A general Review of the probable Larvivorous Fishes of India. Rec. Malaria Surv. India **6**(4):631-648, 7 pls., 36 refs. A general review of the literature on the use of fish on controlling mosquito larvae in India from 1900-1930.

217.* PRENDEL', A. R., ZAGOROVSKII, N. A. AND G. S. FUTRAN. 1932—Data on the Acclimatization of Gambusia in the U.S.S.R. Med Parasitol. Dis. **1**(5-6): pp. 261-264, 10 refs. An account is given of observations in Odessa in 1930-32 to determine whether Gambusia can thrive under the climatic conditions of southern Ukraine. Notes

on its biology are included. It was found that the fish can survive the winter (in a pond in which the water was covered with ice for 3½ months), and multiply in large numbers during the summer and autumn without being given artificial food. They lived for several months in water the salinity of which was gradually increased from 0.5 to 1.5 per cent but died in a few days in water containing 2 per cent NaCl. They also lived in naturally brackish water in drainage ditches, in which the salt content did not exceed 0.6 per cent. This power of adaptation to brackish water is of special importance on the northwestern coast of the Black Sea, where the stagnant water in which mosquitoes breed in spring often becomes brackish in summer.

218.* QUAYLE, H. J. 1906—Mosquito Control Calif. State Bull. **178**: 55 pp. In California the stickle-back fish, *Gasterosteus catapiractus* is of some importance in permanent pools.

219.* RADCLIFFE, L. 1915—Fishes destructive to the Eggs and Larvae of Mosquitoes. Dept. Commerce, Bur. Fish., Economic Circular **17**: 19 pp., 28 figs. In considering the fish that are suitable in the United States for destroying the early stages of mosquitoes, the habits of any particular species of mosquito and its usual breeding places must be considered if success is to be attained. Some breed in casual collections of water where fish could not be introduced while various species of fish are adapted for ponds, ditches, artificial reservoirs or running water.

Fresh water larvicidal fish include: *Fundulus diaphanus, Fundulus dispar, F. notatus, F. chrysotus, F. nottii, Notemigonus chrysoleucus, Carassius auratus, Gambusia affinis, Heterandria formosa, Mesogonistus chaetodon, Centrarchus macropterus, Labidesthes sicculus, Elassoma zomatum, E. evergladei* and *Mollienesia latipinna.*

Those suitable for brackish or salt water: *Fundulus majalis, F. heteroclitus, F. grandis, F. similis, Lucania parva, L. venusta* and *Cyprinodon variegatus.* When fish are sent by train, the journey should be as short as possible, and the water kept at an even temperature and well aerated.

220. RAVERET-WATTEL, G. 1917—Le *Gambusia affinis*, Baired et Girard: Son Utilisation pour la Destruction des Moustiques. (*Gambusia affinis:* Its Use in the Destruction of Mosquitoes). Bull. Soc. Nat. Acclimat. **64**(12):445-451. This paper gives account of *Gambusia affinis*, a small fish that lives almost entirely on the larvae of harmful insects. In waters where mosquito-eggs are laid the larvae constitute the principal diet of *G. affinis*, being devoured in enormous quantities. This fish is considered superior to any other species as a mosquito-destroyer.

221. REBRIN, M. 1938—On the Acclimatization of a new larvicidal Fish in Uzbekistan. Social Sci. Tech. **6**(7):106-107. In view of the successful results obtained in Dakar and Indo-China with the establishment of *Lebistes reticulatus* for the control of mosquito larvae, preliminary small scale observations were carried out in Tashkent in 1937 by N. P. Sokolov. It was found first that though *L. reticulatus* produces young more often than Gambusia, the number in each batch is smaller, although on the whole, the fecundity of the two species is practically equal. Fertility depends on the size, weight and age of the female. The summer temperatures in Uzbekistan appear to be suitable for acclimatizing the fish, but its reaction to winter conditions are still unknown.

222.* RECTOR, NELSON H. 1944—Selection of Anti-Mosquito Methods to Fit Specific Malaria Control Programs. Jour. Nat. Malaria Soc. **3**(3):222-226. A description of general mosquito control methods.

223.* RICE, L .A. 1941—*Gambusia affinis* in Relation to Food Habits from Reelfoot Lake, 1940, with special emphasis on Malaria Control. Jour. Tenn. Acad. Sci. **16**(1): 77-87, 10 refs. In the first paper, an account is given of the results of an examination of the stomach contents of 316 specimens of *Gambusiaa affinis* collected from ten stations in the littoral zone of Reelfoot Lake, Tennessee, in 1939. Plant material, mostly Wolffia, was found to compose 24.7 per cent by volume of the food and animal material 35.6 per cent, the remainder being digested matter or debris. Insects formed 22.4 per cent of the whole, but larvae of Anopheles and Culex comprised only 0.4 and 0.5 per cent and were found in only two and eight stomachs respectively. The food of the young fish was

practically confined to plankton. Experiments showed that Anopheline larvae can usually be identified as such and sometimes specifically identified during their passage through the stomach and intestine, and that the fish devour the larvae readily, but only when the latter are in motion. It is concluded that the dense aquatic vegetation of Reelfoot Lake and small pieces of debris afford so much protection that the fish are of practically no larvicidal value there.

The second paper deals with work in 1940. No mosquito larvae were found in the stomachs of Gambusia collected between 9th and 16th July, although dips from the zone with heavy vegetation showed an abundance of larvae of Anopheles, Culex, and Uranotaenia. However, only large fish had been examined, and it was found that these were not plentiful in this zone but congregated in the shallow water under willows, whereas the smaller fish went among the vegetation and were seen to search for Anopheles larvae among the Ceratophylum and to take them if they moved. In an examination of the stomach contents of a total of 465 Gambusia taken beween 9th July and 14th August from the same stations as those examined in 1939, 20 per cent of the food was vegetable and 80 per cent animal, the latter including 23.5 per cent insects, 13 per cent mosquito larvae, and 5 per cent larvae of Anopheles. Mosquito and Anopheline larvae represented 10 to 25 per cent of the food of 154 Gambusia from an area of heavy vegetation, but were not found in 125 from open water and areas almost free of vegetation. The percentages of stomachs found to contain various forms of food by Barnickol in 1939 and the author in 1940 are compared in a table, the figures for Anophelines being 0.6 and 13.1. The reason for the difference is not known, but various explanations are suggested. The stomach contents of 46 specimens of *Fundulus dispar*, which is present in Reelfoot Lake at the ratio of 1 Fundulus to 40 Gambusia where vegetation is heavy and 1:100 where it is light, bore considerable resemblance to those of Gambusia, but 31.11 per cent of the stomachs contained Anophelines larvae, which formed 10 per cent by volume of the total food. From these data, it appears that both fish are of value in the control of mosquitoes when the fish can reach them.

224. ROCHA, F. 1938—Malaria Control at "Mina de S. Domingos." Arg. Inst. bact. Cam. Pest. **6**(2):123-127, 2 maps, 2 graphs, 17 refs., 1930. Op. Cit. **7**(3):363-374, 2 graphs. The use of Gambusia was planned for 1938.

225.* ROCKEFELLER FOUNDATION. 1921—Fighting Mosquitoes with Fish. 7th Ann. Rept. Internat. Health Bd., Rockefeller Foundation, pp. 20-23, 1920, New York. The efficacy of minnows (*Gambusia affinis*) as destroyers of Anopheles larvae is emphasized. In 89 per cent of the waters in Hinds County, Mississippi, in 1919 and in 85 per cent in 1920, mosquito breeding was completely controlled by fish. This method is now being adopted in Mexico, Central America and Peru throughout the region where yellow fever occurs.

226. ROCKEFELLER FOUNDATION 1922—(Laboratory Experiments with *Gambusia affinis*). Inter. Hlth. Bd,. Annual Report, 8th, 1921, 168 pp. New York. Laboratory experiments with *Gambusia affinis* shows that the fish eats about 50 larvae a day.

227.* ROCKEFELLER FOUNDATION 1924—Use of Fish for Mosquito Control. Intern. Hlth. Bd. of the Rockefeller Foundation. 120 pp., 217 refs., 10 figs., New York. Summary of the literature of the use of fish for mosquito control, accompanied with a short biology and photographic plates of most of the fishes cited.

228.* ROOT, F. M. 1924—Notes on the Mosquitoes of Lee County, Georgia. Amer. Jour. Hyg. **4**(5):449-455. Practically all the permanent and semi-permanent pieces of water are densely populated by Gambusia, and the abundance of Anopheline larvae seems to depend on the amount of shelter provided by aquatic vegetation.

229. ROSS, SIR RONALD. 1911—Fish as a natural enemy of mosquitoes. In his Prevention of Malaria, 1911, pp. 267-269, London. Between 1889 and 1890 Ross investigated the use of fish and found minnows in India that could each devour in a few seconds a dozen or more larvae. Large fish, however, disclaimed such prey. He noticed also that fish and larvae lived together in ditches and in rice-fields. The immunity of Barbados from malaria he thought might be due to the local fish known as "millions."

230. ROSSI, G. 1935—Come Maccarese pote lonificarsi integralmente nonostante la malaria. (How Maccarese was fully reclaimed in Spite of Malaria). Ann. R. Ist. sup. agrar. Portici 7(3):163-379, 15 figs., 41 pls., 11 pp. refs. Measures against Anophelines included stocking all waters with Gambusia.

231.* ROULE, S. 1934—Role des poissons larvivores dans la prophylaxie du paludisme. (Thése) Med. 8vo. (8), 61 pp., 2 pp. refs., Paris, E. Le François. The fish used are classified according to whether they feed on the bottom or surface of shallow water, or in deep water. The morphological and biological characters governing larvivorous tendencies in different families of fish are discussed. These characters are most marked among the Poeciliids, which include the species of the genus Gambusia, the bionomics of which are discussed. These are the most hardy and voracious of larvivorous fish, adapting themselves to all geographical conditions and types of physical phenomena of pond life, and succumbing only to very prolonged cold. In localities in which mosquito larvae are protected by aquatic plants it is not possible to exterminate them solely by means of Gambusia but where these fish can move about freely in the water, malaria has in many cases disappeared as the results of their introduction. The great advantage of the use of Gambusia is that it is easily introduced and its cost is low. The best results are obtained when it is combined with the use of chemical larvicides, which are required at the beginning of the season and become less and less necessary as the fish increase.

232.* ROY, D. N. 1938—On the Control of Malaria—Mosquitoes in Bengal by the Use of Predacious Fish and on the Habits of two of them. Jour. Malar. Inst. India 1(4):405-416, 11 refs. The use of fish for the control of mosquito larvae is discussed, and an account is given of field and laboratory observations on the behavior of *Panchax panchax* and *Barbus phutunio*. The two most important vectors of malaria in Bengal are *Anopheles philippinensis* Ludl., and *A. varuna* Iyen., which breed, respectively, in neglected reservoirs and in weedy and partly shaded reservoirs. The presence of duckweeds (Lemna and Azolla) alone was sufficient to interfere with the action of fish on Anopheline larvae, so that unless it is possible to remove vegetation or prevent its growth, their utilization in the control of malaria will be impracticable. It is concluded that, although fish may aid in checking the multiplication of mosquitoes in general, the practical benefits likely to be derived from their extensive use for the control of malaria in rural areas in Bengal would be too slight to make it a measure of economic value.

233.* RUIBINSKII, S. V. AND M. S. LEVIT. 1934—Die Fischzucht als Behampfungsmittel der Malaria in der Ukraine. (Fish-breeding as a Method of controlling Malaria in the Ukraine). (In Russian). Rev. Microbiol. 13(2):151-159. In the Ukraine of the endemic centres of malaria occur in districts with vast expanses of water resulting from river floods. Neglected mill-ponds also offer favorable breeding places for mosquitoes, of which *Anopheles maculipennis* Mg., is the chief vector of the disease. As it is planned to use large accumulations of water for breeding fish, investigations were carried out in 1932 on the possibility of rendering the fish-ponds unsuitable for mosquito larvae or using the fish against them. For this purpose, over 50 carp-ponds were examined near Kiev. Measures suggested to prevent the breeding of Anophelines include the removal of vegetation from the water, thus depriving the larvae of shelter from the fish; the improvement of the channels by which the ponds are filled or drained and in which Anopheline larvae are often numerous; dusting with Paris green, which, unlike oil, does not affect the fish; and stocking the ponds with young carp, which feed readily on the larvae. The value of other fish in this respect is discussed, and the introduction of Gambusia is particularly advocated, as experiments have shown that it can be established in the Ukraine.

234. RUKHADZE, N. P. 1934—Gambusia in Abkhasia. Med. Parasitol. 3(1):60-68, 7 refs. Since the introduction of Gambusia in Abkhasia (Transcaucasia) from Italy seven years ago, this fish has also been liberated in Russian Central Asia, North Caucasus and Odessa. In Abkhasia, numerous breeding ponds have been established, and nearly all reservoirs that are likely to harbor Anopheline larvae are now stocked with this fish. In the Sukhum district, Gambusia was very effective in 1932 in 78 per cent of the total area of water infested, and in four years the amount of material used for oiling has been reduced by almost 50 per cent. Gambusia destroys the eggs and pupae, which

are scarcely affected by oil or Paris green. The fish distribute themselves by entering streams, rivers and swamps after heavy rains. Some are carried by water during spring floods and remain in pools left after these recede, which are a prolific source of Anophelines. The efficiency of Gambusia has also been demonstrated in ponds and lakes formed by mountain springs, but as the water in these is too cold for the fish to breed, they have to be artificially stocked. Artificial, temporary water reservoirs are stocked with Gambusia at the rate of 1 fish to 10 sq. ft. of water surface if there is no vegetation, the number being increased in proportion to the density of the vegetation. Usually, most of the fish present in temporary accumulations of water die after these have dried up; in order to avoid the necessary work of restocking deep pits should be dug at the bottom of such pools, ditches or ravines, as some of the water and a few fish will remain there till the next heavy rain or flood. The presence of iron oxide, or even traces of it, in the water is fatal to the fish. In the laboratory, they died when kept in water supplied by recently installed iron pipes.

The chief enemies of Gambusia in Abkhasia are wild and domestic ducks, and snakes. In one locality the fish were protected from the snakes by spraying kerosene on the surface of the water, or strewing sulphur on the soil around the reservoirs. Administrative measures had to be taken against the population, who made wide use of Gambusia for feeding their ducks, geese and even pigs.

235.* RUSSELL, P. F. AND V. P. JACOB. 1939—Some Experiments in the use of Fish to control Anopheles Breeding in Casuarina-pits. Jour. Malar. Inst. India **2**(3): 273-291, 3 pls., 5 refs. The experiments on larvivorous fish described in the second paper indicate that in the sandy casuarina pits, in which vegetation is scanty, good control of the larvae might be obtained by using *Gambusia affinis*. It would, however, be necessary to have a suitable nursery to provide a constant supply of fish to replace those lost in various ways, and to employ a "fish patrol" to see that all pits were adequately stocked and to remove occasional patches of vegetation. The cost of such a method is discussed, and it is again concluded that although breeding is not completely eradicated, the method is sufficiently cheap and effective to be applied as a routine measure. Experiments were also carried out with two local species of fish, but neither was as effective as Gambusia and it seemed unlikely that they could be rendered more efficient by artificial means.

236.* RUSSELL, P. F., KNIPE, F. W., AND RAO H. RAMANATHA. 1942—On Agricultural Malaria and its Control with special reference to South India. Indian Med. Gaz. **77**(12):744-754, 31 refs. Introduction of Gambusia into 1,464 wells after chlorination to kill larger fish.

237. SAO PAULO. 1913—Directoria Geral Do Servico Sanitario. Instruccoes sobre a prophylaxia do impaludismo. Sao Paulo, Diario official, 9 pp. W. P. Seal, of the U. S. Bureau of Fisheries, suggested for use in this region, a small fish called the "Anablips," which is found in the fresh waters of South America and which is known to be an insectivorous feeder. In addition to the fish recommended by Dr. Goeldi, the "guarugaru," one of the Poecilidae family of southern Brazil is said to have all the qualities that should make it useful except that it feeds on decaying organic matter as well as insects.

238.* SCIENCE 1921—Top Minnow as Yellow Fever Eradicators. Science **53**(1375):423-433. In view of the success that has attended the use of the top minnow (Gambusia) in eradicating malarial mosquitoes in various parts of the United States this method has been adopted for the eradication of Yellow Fever mosquito (*Stegomyia fasciata*) at Tampico, Mexico, in preference to oiling.

239.* SCIENCE 1927—The Use of American Fish to fight Italian Mosquitoes. Science **66**(1701): suppmt. p. xii. Large numbers of Gambusia have been introduced from America into Italy to destroy mosquito larvae. This fish appears to flourish in all the malarial regions of Italy from Istria to Sicily even better than in its native land. It does well in small ponds or large lakes and in fresh or slightly salt water. It can resist high temperature and other unfavorable conditions and survive in the smallest residuary puddles.

240. SEAL, W. P. 1908—Fishes and the Mosquito Problems. Scientific Amer. Supplement **65**:351-352. Requirements for anti-mosquito fish.

241.* SEAL, W. P. 1910—Fishes in their relation to the mosquito problem. U. S. Bureau of Fisheries, Bull. 1908 **28**(2):833-838. Requirements for anti-mosquito fish.

242.* SEALE, A. 1917—The Mosquito Fish, *Gambusia affinis* (Baird and Girard), in the Philippine Island. Philippine Jour. Science Sec. D, **12**(3):177-187, 1 fig. In 1905 an experiment of stocking the ponds and breeding pools of mosquitoes in the Hawaiian Islands with mosquito-feeding fish was tried, the species selected being *Gambusia affinis*, from Texas. These fish have multiplied rapidly. Several hundred thousand have been bred and distributed from the few hundred introduced. They effectively clear the water of mosquito larvae and of the egg-masses of *Culex pipiens* on the surface. In 1913, 24 of these fish were brought from Honolulu to the Philippine Islands; these now number more than 7,600 in the streams and swamps of the Philippines. They have proved capable of maintaining themselves in ponds already stocked, with *Micropterus salmonoides* (black bass) and such native fish as *Ophiocephalus straitus* and *Therapon argenteus*, and have been multiplied in the presence of these voracious species. There remains no doubt that within a few years they will materially decrease the numbers of mosquitoes and greatly assist in eliminating malaria from the Islands.

243.* SEBASTIAN, V. 1942—On the Role of *Etroplus suratensis* (Bloch) and *Etroplus maculatus* Bloch in the Control of Mosquitoes. Jour. Bombay Nat. Hist. Soc. **43**(2):271-273. Having observed in Cochin that *Etroplus suratensis* would snap at any object thrown into the water in its vicinity and concluded that it would similarly attack mosquito larvae even though it did not swallow them, the author experimented with *E. maculatus*, and found that when larvae were thrown into the water the fish became very active and began to prey on them, often snapping at one and rejecting it several times before actually swallowing it. Some larvae were killed and not swallowed. He concluded that a study of stomach contents alone is not sufficient to show the larvicidal value of fish, and that their feeding habits also should be taken into consideration.

244. SELLA, M. 1921—Campagna Antimalarica nella Spagna (Antimalaria Work in Spain). El Sol. (Madrid). Among the methods that the author proposes to employ are drainage, oiling, screening, quinine prophylaxis, and the use of Gambusia. The United States Bureau of Fisheries has dispatched shipments of this fish to Spain, and its acclimatization is to be attempted.

245. SELLA, MASSIMO. 1922—On Use of Fish in Malaria Control. Ill Policlinico, Roma, sezione pratica, **29**: Mar. 13, 20.The author insists on the use of fish especially *Gambusia affinis* for the control of malaria.

246. SELLA, M. 1926—A new Means of combating Anopheles in Italy; An Account of the Acclimatization and Progress of Gambusia. C. R. Cong. Ins. Paludisme, reprint, 16 pp., Rome. After concluding that indigenous fish are of little or no value against mosquito larvae in Italy, the author discusses the success obtained by the introduction of Gambusia. Complete destruction of the larvae by the fish is possible provided that the vegetation is controlled. Horizontal vegetation impedes the activities of the fish, whereas vertical vegetation does not.

247.* SELLA, M. 1927— I pesci larvifagi e l'esperimento di campagna antimalarica con le Gambusie a Rovigno d'Istria (Larvivorous Fish and the experimental antimalaria Campaign with Gambusia at Rovigno, Istria). Riv. Malariol. **6**(6):881-909, 10 figs. A short account is given of the use in various parts of the world of fish against mosquito larvae. It is stated that the excellent results achieved by Valle and Sepulcri were obtained with *Alburnus lucdius* and not *Leuciscus erythrophthalmus*. Larvicidal fish (Gambusia) introduced in 1922 into Italy from Spain have thrived and have proved harmless to the native species.

An anti-malaria campaign, based exclusively on the use of Gambusia, was conducted in 1926-1927 in a district in Istria that abounds in Anopheline breeding-places, usually artificial watering pools. It was found sufficient to place only a few fish in a pool since they increase rapidly. Thus waters that dry up in summer can be readily restocked yearly, the fish being introduced in autumn and not at the end of winter, to allow time for their increase. Gambusia can resist severe frost if able to shelter in mud, and the lack

of mud is probably the reason why it has not survived the winter in some parts of Venetia. The fish are not very active in spring, and it may be necessary to clear away grass in the pools, Paris green may be employed as an additional measure, but it is not indispensable. Gambusia can live in water too salty for *Anopheles maculipennis* Mg., (*Claviger* auct.) and *A. sacharovi* Favr. (*elutus* Edw.). It rarely lives for two years. The cost of using fish was one-third that of dusting with Paris green, and the results were satisfactory.

248. SELLA, M. 1929—Gambusie e verde di Parigi nella lotta antimalarica a Rovigno (Relazione per il 1928) e cenni sulla lotta in Istria (Gambusia and Paris green in Anti-malaria Work at Rovigno (Report for 1928) and notes on the Campaign in Istria). Riv. Malariol. **8**(4):357-392, 4 figs. For the control of mosquitoes in 1928, as in previous years, Gambusia was used alone in some districts, though in one Paris green was employed. The efficiency of Gambusia was clearly demonstrated.

249.* SERGENT, ET. 1932—Essai de peuplement d'une riviere d'algerie (La Reghaia par les gambouses). Arch. Inst. Pasteur Alger. **10**(3):348-355. An account is given of an experiment carried out in Algeria from 1929 to 1931 on the establishment of *Gambusia holbrooki* in a stream for the control of Anopheline larvae. Batches of fish were released at frequent intervals at various points. It is concluded that in parts of the stream where the bed is narrow and the current during the winter floods is swift, it is necessary to restock with Gambusia each spring, but in the wider parts the winter floods do not prevent its breeding, and it may spread for considerable distances from the point of release. The presence of large fish did not appear to check the multiplication of Gambusia, and where it was sufficiently numerous, it entirely prevented the breeding of Anophlines in spite of the presence of filamentous green algae, which in some places formed a thick mat.

250. SERGENT, ET. 1939—Du Cannibalisme des gambouses et d'un moyen d'y remedier. Arch. Inst. Pasteur Alger. **17**(1):139-142. 2 figs. Fish of the genus Gambusia are very voracious and if, when they are being used for the control of Anopheline larvae, they are placed in an insufficient volume of water, they devour their own young. To obviate this, the author has evolved a cage to contain the gravid females that is made of wire netting with a mesh sufficiently large to allow the escape of the fry and of males. The cage is kept on the bottom and marked by a floating cork attached to a string. In experiments, the number of fish present at the end of a month in two cement basins of equal size was always greater in the one in which the females were caged.

251.* SERGENT, ET., CATANEI, A., TRENSZ, F. AND A. SERGENT. 1932—Experience de destruction des anopheles au moyen des gambouses dans un barrage-reservoir algerien. Arch. Inst. Pasteur Alger. **10**(2):153-156. An account is given of an experiment carried out in Algeria on the establishment of *Gambusia holbrooki* in a reservoir for the control of Anopheline larvae. The reservoir was filled during the third week of April. Several hundreds of fish were released at once, and 200-300 during the succeeding weeks until July. Culicine larvae and pupae which were first observed about 4th of May, were abundant by the 21st, and on the 26th the first Anopheline larvae appeared. At first the fish were not sufficiently numerous to be effective, and on the 27th of May part of the edge was oiled to check the mosquito breeding. By the 30th of May all Anopheline larvae had disappeared, but Culicine larvae were still present, and the banks that had been oiled were, therefore, cleared of vegetation. Gambusia became more numerous and by the 18th of June the mosquito larvae had disappeared.

252. SEVERN, (A. G. M.) 1926—The Mosquitoes of Hongkong. Caduceus, Jour. Hongkong Univ. **5**(1):5-9. Two or three indigenous species of small larvicidal fish occur in ponds and streams, but are less common than formerly. *Macropodus opercularis* (Chinese Paradise Fish) feeds voraciously on mosquito larvae and even pupae.

253.* SEWELL, R. B. S. AND B. L. CHAUDHURI. 1913—Indian fish of proved utility, as mosquito destroyers. 1913, 25 pp., Calcutta. Summarized in Tropical Diseases Bulletin **2**:652-653, 1913. Observations on the effectiveness of *Barbus stigma*. Experimental confirmation of the observations revealed that the fish can devour 100 larvae in twenty-four hours. It is thought that Haplochilus was the leading larvae-destroyer and

that the presence of weeds in the water does not, on the whole, prevent the complete eradication of larvae.

254. SFARCIC, A. 1927—Malaria in Dalmatien und ihre Bekämpfung (Malaria and its control in Dalmatia). Abh. Gebiete Auslandsk. Hamburg, Univ. Ser. d (Med.), **26**(2):532-538, 3 figs., 2 refs. The establishment of *Gambusia affinis*, transported from Brazil, has been of particular value owing to the scarcity of water.

255. SHAPIRO, J. M. 1931—Report on the Malaria Research Unit. Ann. Rep. Dept. Hlth., Palestine, 1930, pp. 109-110. Experience has shown that though top-minnows, *Gambusia affinis*, feed voraciously on larvae in captivity, they are less valuable under natural conditions.

256.* SHAPKIN, L. A. 1940—*Gambusia affinis* et *Leucaspius delineatus* dans la lutte contre les larvae de l'Anopheles. Med. Parasitol. **9**(5):511-514, 1 fig. *Gambusia affinis holbrooki*, which destroys Anopheline larvae, was introduced into the Province of Dniepropetrovsk (central Ukraine) from Abkhazia in 1934. This species multiplied in the summer and survived the winter, but died in most of the waters in spring. A study was therefore made of the types of water in which it would thrive. The Steppe rivers appeared to provide the most suitable conditions, since they are shallow, have a slow current, sloping banks, a muddy bed and abundant aquatic vegetation. Artificial reservoirs should be at least 40 in. deep and protected from wind. They should have sloping banks, submerged aquatic plants, a rich zooplankton, and a muddy bottom free from hydrogen sulphide; the presence of springs is desirable. Analysis of the stomach contents of these fish showed that they prefer animal to vegetable food, but are able to survive on protozoa and algae for an indefinite period. They were destroyed by pike and perch, but not by carp. Other natural enemies in the Province include the predacious bug, *Notomecta glauca* L., which is present in numbers wherever Gambusia is abundant, and ducks. Since gravid females were common at water temperatures of 11-12° C. (51.8-53.6° F.), it is suggested that waters infested with Anopheline larvae should be stocked with Gambusia in April so that the first brood would be reproduced in May. Superfluous aquatic vegetation along the banks should be removed as it affords shelter to the mosquito larvae. As a result of breeding Gambusia under suitable conditions, it was available in large numbers in 1938, and over 600 acres of waters were stocked with it.

Leucaspius delineatus is the most effective of the local fish that feed on Anopheline larvae. Owing to the position of its mouth, it feeds on objects occurring at or near the surface of the water. It remains near the banks, where mosquito larvae occur, and is very active and voracious. It spawns from April to the end of June, and unlike Gambusia, overwinters in any fresh water that does not freeze to the bottom. Some 25 acres of water were stocked with this fish in 1938. It was found that the most effective rates of release were 5 per 10 sq. ft. for Gambusia and 7-8 for Leucaspius.

257.* SHAW, F. R. 1925—Effect of Temperature on Aquatic life in Cisterns. Public Health Bull. **156**:65-71. The effect of different temperatures upon Gambusia.

258. SHIRCORE, J. O. 1927—Tanganyika Territory: Annual Med. Rept. for the year ending 31st Dec. 1925, 147 pp., Dar-es Salaam. The author reports that hte following fish have been used in the control of mosquitoes in Africa: *Fundulus gardneri*, *Carassius auratus*, *Cyclocheilichthys apogon*, *Betta pugnax*, *Tilapia nilotica*, *Gobius criniger* and the genus Galaxias.

259.* SICAULT, G. 1934—Note sur l'adoptation du *Gambusia holbrooki* aux eaux salees. Bull. Soc. Path. exotique **27**(5):485-488. In view of the fact that in Morocco Anophelines breed in brackish water in certain lagoons, experiments were undertaken to determine whether or not *Gambusia holbrooki* could be used for their control. It was found that these fish could be transferred from fresh water containing at least 11 gm. sodium chloride per liter without causing their death or diminishing their capacity for feeding on mosquito larvae. By progressively increasing the quantity of NaCl, it was possible to accustom them to a concentration of 33 gm. per liter, but at 18 gm. they did not feed so readily, at 26 gm. feeding ceased and there was an appreciable mortality, and at 35 gm. all the fish died.

260. SICAULT, G. 1935—Note sur l'epandage du vert de Paris per avion au Maroc. Bull. Inst. Hyg. Maroc. **1-2**:93-102. Larvicidal fish cannot be established against Anopheline larvae in large areas of the extensive marshes in the Rharb district of Morocco because the marshes dry up entirely in years when there is little rainfall.

261. SICAULT, G., MESSERLIN, A., LUMMAU, J. AND J. FRITZ. 1935—Le paludisme dans le Rharb. Bull. Inst. Hyg. Maroc. **1-2**:5-91, 7 pl., 4 pp. refs.

262. SIN, P. 1939—Can Paris-green Kill Fish? Bengal Public Health Jour. **1**: pp. 9-12.

263.* SMITH, J. B. 1902—Report on mosquito investigations. N. J. Agric. Expt. Station, Annual Report **23**:511-593. For combating salt-marsh mosquitoes, the author recommends the use of the killifish.

264.* SOKOLOV, N. P. 1936—L'Acclimatisation du *Gambusia patruelis* in Asie centrale. Riv. Malariol. **15**(5):325-344, 11 figs., 25 refs. An account is given of the introduction of Gambusia into Turkestan in 1935 for the control of Anopheline larvae in rice-fields and of observations of the species made from May to September of that year. The temperature of the water in the fields was very high during the day. Both the temperature and the oxygen content varied considerably at different hours, but the pH changed only slightly, the reaction being almost neutral. The fertility of Gambusia depended on the age of the fish, females 2-3 years old which are 45-50 mm. long, being the most productive. The young reaches maturity in the very short period of 36-40 days, so that 4-5 generations can occur during one season from the sowing to the ripening of the rice. Analysis of the stomach contents showed that Culicines represented 20 per cent of the food of the adults and Anophelines 32.8 per cent. In the young fish the only mosquito larvae found were Anophelines; they represented 64.8 per cent of the food. The numbers of Anopheline larvae in rice-fields containing Gambusia were reduced by about 90 per cent as compared with fields not stocked with the fish. The fish were introduced at the rate of 2 or 3 per square yard.

265.* SOUTHWELL, T. 1920—Fish and Mosquito larvae in Bengal, Bihar and Orissa, India. Ann. Trop. Med. and Parasitol. **14**(2):181-186. The author dealt with various permanent freshwater areas such as wells, borrow-pits, tanks, etc. He lists the following species as being of special importance as larvivorous forms: *Haplochilus panchax* (*Panchax panchax*), *H. melastigma* (*Aplocheilus melastigma*) and *H. lineolatus* (*Panchax lineatus*), *Ambassis nama*, *A. ranga*, *Trichogaster fasciatus* (*Colisa fasciata*), *Badis badis*, *Barbus phutunio*, *Anabas scandens* (*Anabas testudineus*), *Wallago attu*, *Perilampus* sp. (*laubuca* sp.), *Danio rerio* (*Brachydanio rerio*), *Barilius* sp. and *Rasbora daniconius*.

266.* SOWERLY, A. DE C. 1927—Fighting Mosquitoes with Fish. China Jour. **7**(2): 104, 1 pl. *Polyacanthis opercularis* (Paradise fish) occurs in the rivers and creeks around Shanghai and readily devours the larvae of mosquito, but not being a rapid breeder, it is unlikely to be of great value for mosquito eradication. The top-minnow, *Gambusia affinis*, is extremely useful, and it is proposed to start a hatchery for the breeding of this fish where they can be protected from the cold, which destroyed most of those imported from Manila.

267. STEAD, D. J. 1907—Fishes as mosquito destroyers in South Wales. Agric. Gaz. N. S. Wales **18**: pp. 762-764. Requirements for anti-mosquito Fish.

268. STRANGWAYS-DIXON, D. 1940—*Gambusia affinis holbrooki;* imported Anti-malaria Fish in East Africa. E. Afr. med. Jour. **16**(12):450-455. After discussing the use of fish of the genus Gambusia against Anopheline larvae and briefly describing their life-history and habits, the author gives an account of their first successful introduction into East Africa, in 1937, together with recommendations for their rearing and distribution. In June 1939, distribution centers were established in most provinces in Kenya, and were in the course of establishment in Uganda.

269. STRICKLAND, C. 1913—The colonization of "millions" in the Malay Peninsula, Federated Malay States. Report by the traveling medical entomologists. Kuala, Lumpur. 4 pp. The author states that "millions can be used for stocking tanks and other recep-

tacles to reduce the Stegomyia and Culex that abound in such great numbers in the Malay Peninsula.

270.* SUNDER, LAH HORA. 1927—The Use of Fishes for the Control of Mosquitoes. Indian Med. Gaz. **62**(4):187-188. Investigation made in response to inquiries show that the Department of Fishery, Madras, is the only organization that can supply larvicidal fish at present. *Aplocheilus melanostigma, Panchax parvus* and *P. striatus* are generally kept in stock. The utility of these species for destroying mosquito larvae has been proved, and they have been used extensively for anti-malarial work.

Inspection of tanks containing large carp, such as *Catla catla, Labeo rohita* and *Cirrhina mrigala* as well as small fish of the typical larvicidal genera such as Aplocheilus, Ambassis, Chela and Barbus (Puntius) failed to reveal a single mosquito larva. Mosquito breeding in one tank were effectively eradicated by the introduction of individuals of *Panchax* (*Haplochilus*) *panchax*.

271.* SWEET, W. C. AND B. A. RAO. 1934—Notes on Malaria in Nysore State. Part V. The Control of Anopheline Breeding in Bangalore City and its Cost in Nysore State. Rec. Malaria Surv. India **4**(2):95-110, 5 graphs, 4 refs. In an experiment to determine the best control method for the above area the wells were at first treated by stocking half of them with *Gambusia affinis* (introduced from Italy in 1928) and applying Paris green to the remainder; although the latter method was more efficient, the use of Gambusia produced satisfactory results, and as it is cheaper, it was adopted throughout the city.

272. SWELLENGREBEL, N. H. 1916—Quelques notes sur la destribution geographique des anophelines et du paludisme a Sumatra. Annales de l'Institut Pasteur **30**:593. In Samarang, Java, de Vogel found the first ponds along the coast without larvae. In old half dried-up ponds without fish, larvae were found in abundance, among them Anopheles.

273.* SWELLENGREBEL, N. H. AND ETC. 1920—Observations on the Larvae-destroying Action of small Fish in the Malay Archipelago. Jour. Trop. Med. and Hyg. **23**(7):77-79. The following have been observed as larvae-eating fish: *Haplochilus panchax, Ophiocephalus striatus* and *Dangila cuvieri*.

274.* TIRUNARAYANS-IYENGAR, M. O. 1919—On tthe Results of a Mosquito-Survey of Indore City. Indian Jour. Med. Research, Special Indian Science Congress Number, pp. 26-39, 4 plates. Calcutta.

275. TOP-MINNOWS AS YELLOW FEVER ERADICATORS. 1921—U. S. Bureau of Fisheries, Bull. **71**. Prevention of Stegomyia breeding in barrels, tanks, and other receptacles used for catching and storing rain water for domestic purposes, in which crude oil could not be used. Mexico and Central America.

276.* TOUMANOFF, C. 1933—Sur un premier essai d'acclimation au Tonken de *Girardinus guppyi*. Remarques sur le facteur thermique de l'activite larvicide de ce poisson. Bull. Soc. Path. exotique **26**(4):632-638, 2 refs. Details are given of the rearing in the laboratory at Tonkin of *Girardinus guppyi*, a fish imported from France, with a view to its establishment for the destruction of Anopheline larvae. It was found that both in the laboratory and in pools exposed to the open air this species is capable of intensive reproduction under the climatic conditions of Tonkin. Experiments to determine the effect of temperature on its activity showed that the average number of larvae consumed daily varied, according to the size of the fish, from 3 to 17 at 16-20° C. and from 22 to 57 at 27-30° C. The results indicate that the activity of the fish will vary at different seasons of the year and that they will probably be most useful during the summer months, which coincide with the rainy season when the application of larvicides is most difficult. Moreover, the rapid development of mosquito larvae at this season would necessitate frequent treatment. In experiments with indigenous larvivorous fish captured in the course of surveys at Tonkin, *Haplochilus javanicus* and *Macropodus cupanus* showed but slight activity during the cold weather in March, but small individuals of *Rasborichthys helfrichi* were more effective.

277. TRABUT, L. 1928—Role des poissons dans la lutte contre le paludisme. Bull. Agric. Algerie-Tunisie-Maroc **34**(4):61-63. Several small species of fish that feed on

mosquito larvae and are able to live in ditches and pools containing small quantities of water occur in Algeria. The most valuable in this respect are *Tellia apoda*, *Cyprinodon fasciatus* and *C. iberus*. The author considers that the last-named, which occurs in southern Oran, would be the most useful to introduce into the marshes of the Tell. He cites an instance that came under his observation thirty years ago in which a garrison near a swamp in which *C. iberus* was abundant remained in good health while a neighboring garrison near a swamp in which this fish did not occur malaria was severe. The results of the introduction of *Gambusia holbrooki* into Corsica are quoted. This fish has recently been introduced into Algiers.

278.* TRAUSMILLER, O. 1932—Ueber die Grenzen der Malaria-Bekämpfung mittels Gambusien. (On the Limits of Malaria Control by Means of *Gambusia holbrooki*). Arch. Schiffs-u. Tropenhyg. **36**(10):530-539, 4 figs., 19 refs. This paper describes the successful control of Anopheline larvae by *Gambusia holbrooki* in two Jugoslavian Islands in the Adriatic where the larvae chiefly occur in rain-water ponds used for watering cattle. On one island, following the original importation of 200 specimens in August 1924, the fish became established everywhere, surviving the abnormally severe winter of 1929-30. As a result, Anopheline larvae became rare, and the incidence of malaria was greatly decreased. At the beginning of the work, the ponds were kept clear of vegetation, but this was subsequently found to be unnecessary. The fish multiplied to such an extent that they penetrated even the densest vegetation in search of food. On the other island, in which malaria was rife in places, *G. holbrooki* was introduced in 1927, and by 1929 larvae were scarce in the ponds, where no attempt to clear the vegetation had been made, and in a small coastal lake containing brackish water that had been a most prolific breeding-place. The adult mosquitoes disappeared from villages, and acute cases of malaria no longer occurred.

279.* U. S. PUBLIC HEALTH 1921—Prompt Mosquito Control by use of the Top-minnow, Gambusia. Public Health Rept. **36**(36):2220-2221. A case is recorded in which the numbers of Anopheline larvae were greatly checked by the introduction of top-minnow *Gambusia* spp. into a pond.

280. VALLE, V. 1928—Relazione della campagma anti-malarica 1926-1927. (Report on anti-malarial work in Venetia in 1926 and 1927). Riv. Malariol. **7**(2):104-140, 7 figs. Larvicidal fish, Gambusia and another species *Alburnus lucidus*, were distributed. They can destroy up to 20 per cent of the larvae. Instead of prohibiting fishing in waters stocked with larvicidal fish, the use of nets of large mesh would be preferable as they would capture the large fish, such as pike, that prey on the small ones. In the province of Rovigo a cat-fish, *Amiurus nebulosus*, imported from Japan to check the pike, has cleared the waters of nearly all fish and renders difficult the use of larvicidal species.

281. VALLE, V. AND P. SEPULCRI. 1926—Sull'attivita larvifaga d'un pesciolino nostramo (scardola) nota preventia. (On the larviphagous Activity of an Italian Fish. Preliminary Note). Riv. Malariol. V. (N.S.I.) **3**:306-309. In Ventetia the top-minnow Gambusia, which has been imported against the mosquito larvae, cannot withstand the unsual winter temperatures, and unless great expense is incurred in keeping heated breeding tanks in winter it is necessary to renew the supply in spring. A native species, probably *Leuciscus erythrophthalmus*, is said to have given excellent results during the past two years.

282. VAN BREEMAN, M. L. 1920—Further Particulars relating to the Malaria Problem at Weltevreden and Batavia. Meded. Burg. Geneesk. Dienst Nederl. Indie **4**:63-115. At Batavia, fishponds in a well-drained littoral area may be harmless as a source of malaria if (1) only sea-water is allowed to enter the ponds, in order to keep the salt-content as high as possible: (2) a sufficient number of the fish *Chanos chanos* is kept in the ponds to ensure that all under-water and other vegetation is eaten; (3) care is taken that a sufficient quantity *of Haplochilus panchax* is maintained. Such harmless fishponds are to be found north of Batavia. Their drawback is that there is no excess of vegetation as food for *C. chanos* which is, therefore, of less market value. Artificial food might solve this difficulty.

From the hygienic standpoint, however, the abolition of the ponds is the only satisfactory measure.

283. VANDERPLANK, F. L. 1941—Nothobranchius and Barbus species: indigenous anti-malarial Fish in East Africa. E. Afr. med. Jour. **17**(10):431-436, 3 figs., 1 ref. Nothobranchius and Barbus are considered superior to Gambusia for control of mosquito larvae in East Africa in that they are indigenous and widely distributed, and the former at least is able to resist drought by depositing resistant eggs. Notes are given on their habits and the life-history of Nothobranchius, *Pachypanchax playfairi*, probably the most important of the other species native to East Africa that prefer mosquito larvae to other food, has not yet been studied by the author in its natural habitat.

284. VAUGHAN, E. I. 1921—Use of Fish in Mosquito Control. In his report on Yellow fever operations in the Republic of Guatemala, August 19, 1920-March 1, 1921, p. 25.

285.* VILLAIN, G., DUPOUX, R., AND C. MARINI. 1935—Contribution a l'etude de l'anophelisme tunisien et apercu de la lutte antianophelienne dans la Regence. Archives des institute Pasteur de l'afrique du Nord **24**(2):309-342, 12 figs., 9 refs. A brief outline is given of the permanent malaria control works that have been undertaken in Tunisia during the last 5 years. Where these have been completed, there has been a marked diminution in the incidence of the disease. The temporary anti-mosquito measures, which are reviewed, include oiling, dusting with Paris green and the use of *Gambusia holbrooki*, this fish being particularly effective in oases.

286. VIPAN, J. A. M. 1910—Malaria and Millions Fish. Proceedings of the Zool. Soc. **1-2**:146-147.

287. VITOUX, G. 1907—La lutte contre les moustiques. Presse medicale **15**:614.

288. VITTORIO, V. 1926—Considerazioni su alcuni ausiliari alla lotta antimalarica (Auxiliary Measures in the Campaign against Malaria). Ann. Med. nav. colon. **2**:273-292, 25 refs. The possibility of using bats, swallows and fish against mosquitoes, particularly in Italy, is discussed. It is not considered that bats or swallows are likely to be of much value. The fish dealt with are *Gambusia affinis*, *Carassius auratus*, and *Cyprinus carpio*. The first is of great value against mosquito larvae, but it is found necessary in Italy to keep the tanks at a fairly fixed temperature as Gambusia is killed by cold. Also it needs protection from larger fish such as pike.

Carassius auratus feeds chiefly on vegetable matter, and will not attack the larvae if other food is present. If the water can be kept free from vegetation, the fish may prove of some use.

Cyprinus carpio prefers to live in deep water, and the larvae on the surface are only attacked in the absence of other food.

289. VON IHERING, R. 1933—Os peixes larvophagos utilizados no combate a febre amarella e a malaria. (Larvicidal Fish utilized in combating Yellow Fever and Malaria). Riv. med.-cirurg. **41**(7-8):221-234. Various fish known to destroy larvae in America are discussed. In Northern Brazil, the Rockefeller Yellow Fever Service has made extensive and successful use of a number of species for the control of *Aedes* (*Stegomyia*) *aegypti* L., the most effective being *Astyanax bimaculatus* in large tanks and *Hemigrammus unilineatus* in small ones.

The problem of controlling Anophelines in natural breeding-places by means of fish is rendered difficult by the fact that they are not the only source of food as are mosquito larvae in tanks. Furthermore, aquatic plants afford shelter against fish. It is suggested, however, that attempts should be made to find native fish that are effective against Anophelines in order to avoid the need for introducing Gambusia and so distributing an existing fish fauna.

290.* WAGENHALS, H. H. 1919—Fish Control. Public Health Bull. **104**:105-111. Report presented before the First Annual Conference of Sanitary Engineers and other

officers of the Public Health Service Directing Antimalaria Campaign. The author states that fish control around Augusta, Fla., is a valuable, economic and efficient method of controlling malaria. *Gambusia affinis* was used. Various influencing factors which might improve the fishes' efficiency was discussed among the group.

291.* WALSH, E. W. AND R. SOESILO. 1934—Malaria Control in the Netherlands Indies. Trans. Ninth Congress Far E. Assoc. Trop. Med. **2**: pp: 191-200. *Panchax panchax* was found efficient in pools where algae was scarce. *Chanos chanos* was determined a vegetarian but did not feed enough to keep the fish-farm pools clear of algae. Lately *Puntius javanicus* has been introduced into the pools because of the large quantities of plant material needed as food and also the fish has a very rapid rate of growth. *Puntius javanicus* to clear the vegetation and *Panchax panchax* to eliminate the mosquito larvae. These factors would aid in solving the malaria problem in this area. *Anopheles ludlowi* was the vector.

292. WATSON, MALCOLM. 1915—Fish control in the Barbados. In his Rural Sanitation in the Tropics, pp. 301-304, London. Dr. Watson quotes the observation of Dr. Low, who found Culex larvae in a swamp swarming with "Millions."

293.* WELCH, S. W. 1923—Malaria Control Work in Alabama. New Orleans Med. and Surg. Jour. **76**(1):6-9. During 1917-21 anti-malaria work in Alabama has much reduced the seriousness of the problem. In the author's opinion control by means of Gambusia on a large scale is likely to be more effective and economical than any other method, in spite of the many factors that interfere with the successful employment of these fish.

294.* WILLIAMS, JR., L. I. 1941—Malaria on the China Burma Highway. Amer. Jour. trop. Med. **21**(1):1-11, 3 graphs, 3 refs. *Gambusia affinis* was established, and native rearing ponds supply the fish.

295. WILSON, H. C. 1912—Fish as larvicides: a Note on the Treatment of Swamps, Stream Beds, Ponds, Wells, Pools and other Mosquito-infested Areas for the Destruction of Their Larvae. Madras Fisheries Bureau, Bull. **11**:161-172. (Summarized in Tropical Diseases Bull. **5**:453-454. 1915. London.)

296. WILSON, H. C. 1914—Some notes on Larvicides and Natural Enemies of Mosquitoes in Southern India. General Malaria Committee Proceedings, 3rd Meeting, pp. 183-186. The author cites the following genera of fish as natural enemies of mosquitoes: Chela, Rasbora, Barilius, Haplochilus (Panchax and Aplocheilus), and Barbus. In lily pools and small pools, Polyacanthus (Macropodus). In salt water and brackish waters, Therapon and Polyacanthis. Preparation of waters for fish is discussed.

297.* WOODFALL, H. C. 1921—Mosquito Control by Means of Small Fish and Methods Employed for Their Multiplication. Public Health Bull. **125**:111-122. Report presented before the Third Annual Conference of Malaria Field Workers. At Warwick, Ga., surveys showed that malaria was very prevalent. After the liberation of about 2,000 Gambusia in this area mosquito larvae became practically extinct. Discussion followed the paper concerning Gambusia in relation to deep water fishes and how that would affect the larvicidal activities of the top minnow.

298. ZAVATTARI, E. 1934—Acclimatazione della Gambusia e lotta anti-malaria nel Fezzan. (The Acclimatization of Gambusia and antimalarial work in Fezzan). Riv. Malariol. **13**(5):617-622. *Gambusia holbrooki* was imported from Tripoli to Fezzan in 1931 and was found well established there in 1933. Although the water in this region is usually very hard and sometimes very saline, no visible differences were observed in the fish. In the oasis of Traghen and at Murzuch, this species greatly reduced the numbers of *Anopheles multicolor* Camb. In addition to this anopheline, *A. superpictus* Grassi, and *A. sergenti* Theo., also occur in other localities in Fezzan, and all three mosquitoes are vectors of *Plasmodium vivax*.

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Appendix A

Fishes Discussed with Reference Numbers

Appendix B

Mosquitoes Discussed with Reference Numbers

The Morphology of Plagiostomum achromaticum, n. sp.

John G. Mahan

In July 1940, while investigating the "mullet farm" on Piver's Island at Beaufort, N. C., specimens were discovered which are taken to belong to no described species of *Plagiostomum*. The environment was marine and other previously-observed plagiostomids were found in association with these animals. In this, the type locality, I studied about 20 mature individuals, fixing and staining some. The new species is so named from the lack of pigment bands or any pigmentation save in the eyes. The co-type is deposited in the U. S. National Museum as no. 20646, and the other slides of sectioned material are in the collection of the Miller School of Biology (U. Va. no. 830).

Plagiostomum achromaticum, n. sp.

Description.—Body cylindrical with subparallel sides for the greater portion of its length, tapering quickly to head and tail at either end; no indentations on surface of body; body colorless except for pigmented eyes, chitinized interior of vesicula seminalis, and enteric inclusions; total length 2.5 to 3 mm. Epidermis of flattened polygonal cells bearing an even coat of cilia 10 to 15 μ long. Rhabdites uniformly distributed over body in walls of "wasserklaren Raumen"; rhabdites 8 to 13 μ long, about 2 μ wide. No spines or sensory hairs present. Outer circular and inner longitudinal muscles immediately beneath epidermis forming a layer 10 μ in thickness. Parenchyma dense in anterior and posterior regions, loose in mid-region. Paired cerebral ganglia joined by a broad commissure to form a dumb-bell-shaped "brain" located dorsal to the anterior portion of the pharynx; the "brain" composed of an inner fibrous mass with the usual commissures and a cortex of ganglion cell-bodies with small granular nuclei. Eight notable nerve-stems, all paired, have been found issuing from the "brain," as shown in text-figure 1. Paired eyes embedded in anterior nerves from "brain." Mouth opening on the ventral side of the body just under the anterior tip. Pharynx pocket rather greater in extent than in most plagiostomids; Pharynx of the type variabilis, with eosinophilic glands in the walls, opening into a very short histologically different esophagus. Peculiar muscular dorsal diverticulum of pharynx immediately posterior to the "brain" into which the pharyngeal lumen extends; function unknown. Enteron sac-like, extending through about ¾ of body length, composed of non-ciliated columnar endodermal cells; inclusions in the form of large oil droplets and granular materials in wall of enteron; shape varies from cruciform to circular in cross section. No excretory system present. Male and female reproductive systems opening into a posterior common genital atrium communicating with the body surface by a common gonopore in the extreme posterior tip of the body. Male genital system composed of paired testes, vasa deferentia, single vesicula seminalis and penis complex. Testes compact, lanceolate, lying lateral to the enteron in

their anterior portions and dorsal toward their posterior ends which almost touch the vesicula seminalis. Spermatogenesis and spermiogenesis proceed from anterior to posterior in the testes. Vasa deferentia arising on mesial borders of testes and passing posteriorly to unite in entering the vesicula seminalis. Penis complex composed of vesicula seminalis, penis bulb and ductus ejaculatorius, the first two portions being heavily chitinized; the vesicula seminalis and ductus ejaculatorius are surrounded by a thick layer of inner circular and outer longitudinal muscles. Vesicula seminalis anterior and dorsal to the penis bulb. Ductus ejaculatorius short, provided with a papilla which is eversible and a penis sheath. Sperm fusiform with a gelatinous sheath surrounding the head of each sperm before injection into another animal. Female genital system composed of paired vitellaria, paired ovaries, a single oviduct or female genital canal leading into the common genital atrium. Ovaries diffuse, lying in the anterior portions of the vitellaria whence the eggs are discharged into the vitellarium to increase in cytoplasmic mass before passing into the median dorsal

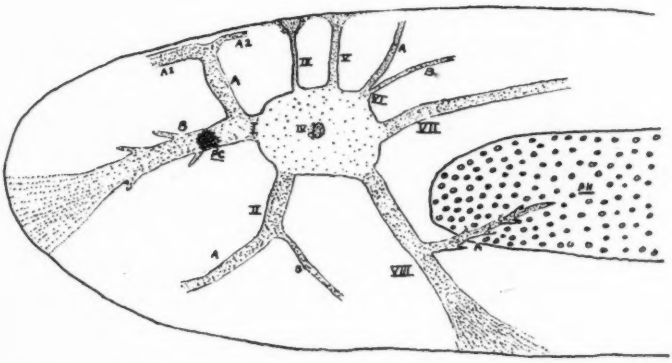

FIG. 1.—Diagrammatic representation of the eight chief nerve stems issuing from the "brain" of *Plagiostomum achromaticum.*

oviduct which transports them to the genital atrium. Vitellaria extensive, loosely cellular in structure, extending through median ⅔ of body in four portions anteriorly in region where testes are lateral and united into a right and a left branch posterior to this. Oöcytes at full development 14 to 20 μ in diameter. Fertilization internal, sperms being injected into the pseudocoele through breaks made in the epidermis of any portion of the body whence they find their way to the oöcytes. No uterus, embryos leaving the mother's body still in the one-celled stage. Common genital duct posterior with ventral ducts of single-celled eosinophilic nidamental glands entering it just within the terminal common genital pore. Chromosome number, n-8, 2n-16.

Discussion.—Incidental to the study of this animal a comparison was made between its parenchyma and that of other representatives of the genus as described and pictured by Böhmig in his *Untersuchungen über Rhabdocoele*

Turbellarien, published in 1890, which has been used as the standard up to the present time. He describes the parenchyma as being composed of two types of tissue, "spongioplasm" or "frame-plasm" which forms an anastomosing net throughout the portions of the pseudocoele not occupied by the "brain," alimentary tract, and reproductive organs, filling the interstices of which is the "hyaloplasm" or "softplasm." Though differences in the amount of each of these tissues at different antero-posterior body levels is noted, no mention is made of differences in numbers of nuclei which would be an important point in determination of the numbers of parenchymatous cells involved. Only very few nuclei are shown in any region. In Tafel XXI, figure 16, he shows only seven nuclei in a third of the parenchymal region which here covers an extensive area.

As noted above, subsequent writers have followed this description, which

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EXPLANATION OF FIGURES

PLATE I

FIG. 1.—Dorsal aspect of a living specimen; E—eye; Ph—pharynx; En—enteron; O—oocytes; SV—vesicula seminalis; Pe—penis; × 100.

FIG. 2.—Median sagittal section: M—mouth; B—brain; PhS—pharyngeal sheath with longitudinal muscles of pharynx lining it; Ph—pharynx; note ciliation of lumina, dorsal diverticulum, and opening into enteron; V—vitellarium, above pharynx, below enteron, and posterior to oocytes; Ep—epidermis; O—oocytes, embedded in parenchymatous stroma. Note one pushed down into enteric tissue. Dark granules are apparent around edges. P—parenchyma; T—testis—posterior region where testis reaches mid-line is shown; NG—nidamental gland; E—enteron; FGC—female genital canal; VS—vesicula seminalis, showing contained spermatozoa; PB—bulb of penis; penis papilla may be noted inverted in the bulb; PS—penis sheath; GA—common genital atrium. × 100.

FIG. 3.—Transverse section through anterior, cruciform, regicn of enteron. EP—epidermis; V—vitellarium in four arms of cruciform enteron; O—oocytes, showing one cut through the median plane, and the other near the periphery. Pseudopodial projections are to be noted in the former and large granules in the latter. These oocytes are surrounded by a network of spongioplasm; WR—"wasserklaren Raumen" or slime reservoirs. Note parallel strands on either side in epidermis; E—enteron, cruciform portion; T—anterior ends of testes; note lateral position shown here as compared with dorsal position in posterior region shown in (Fig. 2-T) P—parenchyma—note abundance of nuclei and greater thickness in ventral region. × 250.

FIG. 4.—Transverse section through middle region of brain. Note nuclei around periphery and central mass of nerve fibers, the middle group forming a commissure. × 680.

FIG. 5.—Frontal section through male copulatory organ. VS—vesicula seminalis, showing radial musculature surrounding it, inner lining of cuticle extending down into bulb, and enclosed sheathed spermatozoa; PB—bulb of penis, showing reticular inner structure. Note muscle fibers running from wall of penis bulb to penis sheath. PP—papilla of penis inverted in bulb of penis. Ciliation, longitudinal, and circular musculature should be noted. PS—penis sheath with radial and circular musculature in wall. × 370.

FIG. 6.—Five stages in spermatogenesis. A—spermagonium showing spireme. B—second meiosis. C—sperm heads, triangular. Note hollow ends. D—whorl of tailed spermatozoa. Note oil globule in head region of each and cytoplasmic mass in which they are contained. E—packet of ensheathed sperms in which the tails have been almost completely resorbed. In this condition they pass to the vesicula seminalis.

fits the area surrounding the oöcytes in mature specimens in my slides very well, for there is chiefly spongioplasm enclosing the oöcytes with little or no hyaloplasm. However, in other regions of the body where pressure is not so great nuclei are abundant and the ratio of hyaloplasm to spongioplasm is high. The ventral portion of the pseudocoele contains denser parenchyma than the

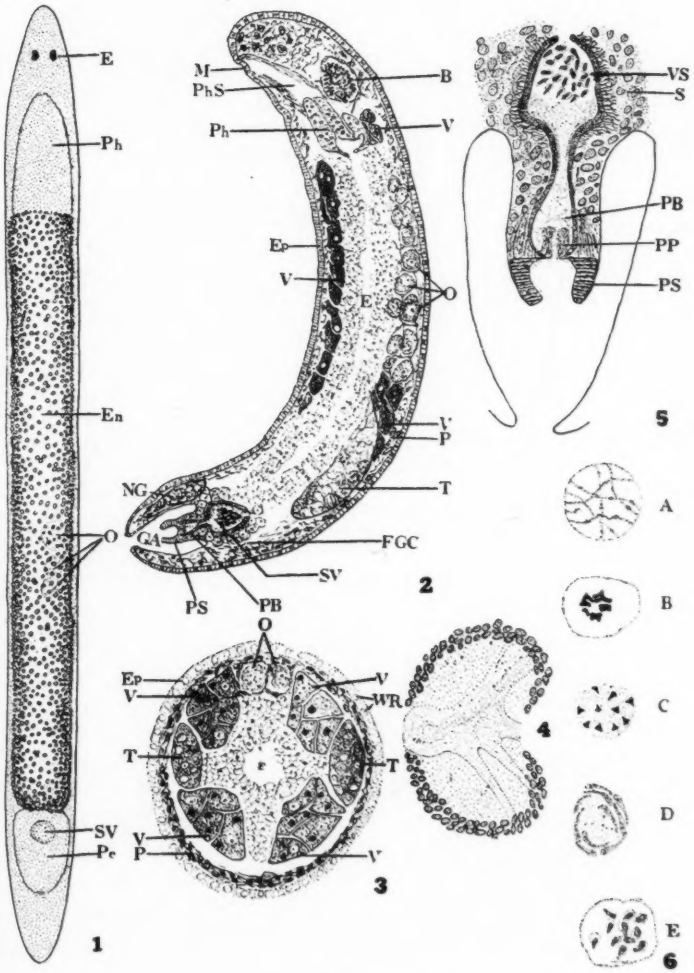

PLATE 1

dorsal. Two regions stand out however as especial examples of closely packed parenchyma and very numerous nuclei, namely, the head region dorsal and anterior to the "brain," and the region around the genital atrium. In these areas, taking a sector comparable to that shown by Böhmig, twenty-five to thirty parenchymal nuclei are discernible on the average in sections ten μ thick. From this it appears that at least in one species the parenchyma differs widely from conceptions held to the present and that these conceptions deserve study and revision.

Of the twenty-eight species of *Plagiostomum* which have been described previously and for which descriptions are available twenty-four are so obviously different from *P. achromaticum* due either to the presence of pigmentation or of two pairs of eyes as not to merit detailed discussion here.

Of the remaining four *P. whitmani* differs markedly in shape, pharyngeal structure, and genital organs from *P. achromaticum; P. girardi* differs in possessing cephalic glands, location of testes, shape of "brain," vesicula seminalis, and penis. There is a considerable resemblance between the pharynx of *P. sulphureum* and that of *P. achromaticum* both in location, musculature, and sheathing but other differences make any confusion of the two highly improbable. Probably *P. achromaticum* resembles *P. dahlgreni* most closely in general body shape, type of pharynx, lack of protonephridia, lack of pigmentation and nearly terminal opening of the genital atrium, but differs from it markedly in size, location and structure of the sex organs, and chromosome number, so that even in this case any confusion between the two would be almost impossible.

Remarks.—Following the suggestion in the paper by Kepner, Stirewalt, and Ferguson on *Plagiostomum dahlgreni* that members of this genus with unsheathed penes be placed in the genus *Hydrolimax*, and only those having a penis-sheath be retained in the genus *Plagiostomum, achromaticum* is placed in the latter genus since a penis-sheath is present.

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A Preliminary Study of the Vegetation of the Region Between Cerro Tancitaro and the Rio Tepalcatepec, Michoacan, Mexico

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Introduction

Cerro Tancítaro is one of a number of isolated high mountains in southwestern Michoacán. It lies about forty miles west of the town of Uruapan, from which it is accessible only by a tiring and rather difficult journey by horseback or on foot. The peak of Tancítaro is the second highest in western Mexico, reaching an altitude of twelve thousand feet, exceeded only by the two peaks of Colima, some seventy-five miles to the west. To the south, scarcely forty miles away, lies the valley of the Río Tepalcatepec, only about one thousand feet above sea level. The pine-clad summit of the mountain is always cold, and is blanketed with snow in winter, while the river valley to the south lies parched with tropical heat throughout the year. Such extreme conditions make the region very interesting for the student of plant distribution, and provide a rich collecting ground, but until recent years this region remained almost untouched by the biologist. Humboldt and Bonpland collected in Michoacán, but apparently they went no farther than the vicinity of the Volcán de Jorullo. Some later collectors went as far as Uruapan, but stopped there, since until 1941 that town was the last point reached by railway. In recent years Mr. George Hinton has collected extensively in southern

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During the summers he made several trips to Mexico as field botanist with the Hoogstraal expeditions from the University of Illinois, and had the opportunity to lay a foundation for his doctoral thesis, a taxonomic study of the Mexican and Central American species of *Zeugites*, a genus of grasses, which was stopped by the removal of type specimens from the principal botanical institutions as a war measure, and by his induction into the armed services of the United States.

Mr. Leavenworth, Lieutenant in the Air Force, was commissioned as a photographer in the Army Air Force in June, 1943 and received his Navigator's wings December, 1943 at Selman Field, Louisiana. He had been overseas since February, 1944. He is survived by his wife, Martha MacGalliard Leavenworth, University of Illinois '43, and a year-old son, William Burgess, of Crawfordsville, Indiana.

The present paper is a timely one because it treats of the vegetation in an area immediately adjacent to that of the celebrated new volcano, Paricutin. The field work was completed only shortly before the eruption of Paricutin.—PAUL C. STANDLEY, Chicago Natural History Museum.

Michoacán and Guerrero, including the valley of the Río Tepalcatepec and Cerro Tancítaro, and these collections have been rich in new species, but no description of the vegetational character of the region has been published.

During the summers of 1940 and 1941 the members of the Hoogstraal Mexican Biological Expeditions spent five months in the area between Cerro Tancítaro and the Rio Tepalcatepec. The expedition made its headquarters the first summer and six weeks of the second summer in the village of Tancítaro, nestled at the foot of the mountain of the same name. The members of the expedition lived in a twelve-room house, which they rented from one of the village officials for a total of twelve pesos the first year, the price being more of a formality than a business transaction. The same spirit of friendship and cooperation which characterized this procedure was noticeable in all of our contacts with the villagers.

The village of Tancítaro lies on a high plateau which stretches southward from the base of the mountain for some miles at an elevation of about six thousand feet before sloping down toward the river valley. Back of the village there is another small plateau which rises abruptly for about five hundred feet above the town. From this plateau the land slopes up to the base of the mountain proper, about six miles away. The base of the mountain meets the plateau at an altitude of seven thousand two hundred feet. Two camps were established on the mountain at altitudes of 7,800 and 10,500 feet, respectively, as bases from which to work. Because of the continual clouds and rain which prevail at these altitudes, all plant collections had to be sent on mules to Tancítaro, where they were dried over ovens made for the purpose.

A few days the first year and six weeks of the second were spent collecting in the river valley, with the town of Apatzingan as headquarters. Here the expedition was fortunate to be able to stay at the hotel of Don Pablo Frisch, who put all available resources at our disposal, as well as acting as guide, interpreter, and agent of general information. Apatzingan is a thriving town of five thousand inhabitants, lying about fourteen miles from the Río Tepalcatepec at its closest point. Situated as it is near the border of the flat river valley, it is the center of trade for the various industries of the area, principally rice-farming and cattle-raising. The high temperatures and constant sunshine, combined with a dry atmosphere, made drying the plants an easy task in this region.

Geology and Physiography of the Region

Cerro Tancítaro is an outlier of the mountains which border the southern edge of the great central plateau of Mexico. During the Cretaceous Period the area now covered by this plateau was submerged, and during the various uplifts following that period there was an enormous amount of extrusion and volcanic activity in the southern part of the plateau. Hundreds of volcanic cones were raised and great areas were covered with igneous material. Cerro Tancítaro is one of the largest and earliest of these ancient volcanoes. Due to its great age it has been eroded and its typical volcanic shape has been lost. It now has the form of a rugged peak, with long, steeply-sloping shoulders radiating to the north and south.

The plateau immediately south of the mountain has an altitude of about 6,000 feet for the most part. It is gently rolling and broken here and there by numerous small volcanic cones, in many of which the crater is still plainly visible. One of these smaller mountains, Cerro San Miguel, lying about three miles southwest of the village of Tancítaro, reaches a height of over 8,000 feet and differs markedly from the surrounding country in the character of its vegetation. South of the village about two miles there is a chain of rocky hills about five miles long. The area covered by these apparently bare, rough ridges is known as the Pedregal, the name by which similar formations are known all through Mexico. This formation is due to a peculiar kind of extrusion which has occurred often along the fault line marking the area of volcanic activity in southern Mexico. The plateau itself is covered by a deep soil and is cultivated to a large extent on the level parts.

For about five miles south of the village of Tancítaro the general level of the plateau does not change much, then it slopes gradually to an altitude of 3,000 feet, where it descends abruptly to the valley below, at about 1,200 feet. The steep edge of the plateau in this area is cut by numerous deep canyons where the larger streams have cut their way into the underlying igneous rocks. At about 1,200 feet the slopes begin to flatten out, and a nearly level plain extends to the river, some sixteen miles away.

Climate

The upper part of the plateau and the mountain receive an abundant amount of rainfall, much greater than the region immediately to the south. Heavy rains fall nearly every day during the rainy season, which lasts from the middle of June until late in September. Clouds are present much of the time on the upper part of the plateau and nearly continually on the mountain. During the late morning and afternoon rain usually falls in torrents. The intensity of the downpour is so great that a rubber bathtub, placed in one corner of the patio to collect water from the roof, would overflow in five minutes. The heaviest and most continual rains fall on the lower slopes of the mountain, below 9,500 feet. The summit is often covered with clouds, but receives less actual precipitation. The rainfall decreases gradually south of the mountain until on the edge of the plateau, at an elevation of 3,000 feet, there are only occasional thunder storms, while in the valley of the Tepalcatepec a real rain is rare.

There are no meteorological records available for the region immediately around Tancítaro, but in Uruapan, located at nearly the same altitude forty miles to the east, the average annual precipitation between 1929 and 1933 was 152.9 cm. The rainfall at Tancítaro is undoubtedly much greater than this, but how much greater there is no way of telling. By far the greater portion of this rain fell in the rainy season, *las lluvias*, in the months of June, July, August, and September. There was often little or no precipitation in November, and that in the winter months was slight. In March and April there was usually no rain at all. This is the period known as *las secas*, the dry season.

The rainfall cycle is the same in the river valley, but the total amount of precipitation is much less. The average precipitation for Apatzingan during

the same period of time was only 66.3 cm., less than one half that of Uruapan. The effective precipitation is even less in the valley because much of the soil is rocky and drains quickly, and the water requirement of plants there is greater because of the intense sunshine, higher temperatures, and dry atmosphere.

The temperature at this latitude does not vary much in summer. During June and July of 1941 our thermometer in Tancítaro registered between 14° and 20° C. except for one high record of 23° C. It is interesting to note that this is slightly but distinctly colder than the temperature in Uruapan, although the elevations of the two towns are nearly the same. In Uruapan the maximum daily temperatures during June and July are often above 30° C., while the minimum is seldom below 14°. Apparently the presence of the mountain exerts a marked influence on the climate of the plateau to the south, for the vegetation there also shows marked differences from that at similar elevations elsewhere. This is because clouds coming from the south and west pile up against the mountain, shutting off much of the sunlight from the plateau in the immediate vicinity. In winter the temperature at night drops below freezing in Tancítaro. Snow covers the peak of the mountain much of the time during this season, and there are occasional light snows on the plateau around the village of Tancítaro. These melt quickly, however, as there is little cloudiness in winter and the temperature during the day often reaches 20° C.

Temperatures in the river valley are high throughout the year. In Apatzingan the average daily temperature for the coldest months, December, January, and February, is above 24° C. The lowest temperature recorded during the years from 1929 to 1933 was 12° C., but this was exceptional, and temperatures of below 17° were rare.

The great differences in temperature resulting from altitudinal variation have given rise to the names, cold country or *tierra fría,* temperate country or *tierra templada,* and hot country or *tierra caliente.* These terms are somewhat loosely used by the natives and apply more to the particular climatic conditions than to the exact altitude, although they are usually defined in terms of altitude. The *tierra caliente* includes the tropical and subtropical regions up to approximately 4,500 feet, the *tierra templada* comprises the region between 4,500 and 8,000 feet, and the *tierra fría* is that land above 8,000 feet.

Agriculture

The only utilization of land in the *tierra fría* is for grazing and the collection of resin for turpentine, but in the area in which most of our work was done grazing was infrequent and the trees had not yet been tapped for resin. In some parts of the forest on Cerro Tancítaro the trees have already been tapped, and it is probable that very soon trees on all parts of the mountain will be used for this purpose, but at present there is little sign of human activity on the south side of the mountain above 8,000 feet. In the upper parts of the *tierra templada* there are large herds of sheep and goats and some cattle, which find good pasturage in the sloping meadows between 6,000 and 8,000 feet. On the level parts of the plateau are numerous cornfields and a few fields of wheat and barley. Many vegetables are grown, among them carrots, radishes,

squash, string beans, tomatoes, onions, potatoes, and sweet potatoes (*camotes*), of which the last named grow unusually well in the region. The main fruit raised in and around the village of Tancítaro is the peach, which flourishes but is very poor in quality because of the lack of proper methods of selection and disease control. Some tropical fruit trees grow in the village, but they bear poor quality fruit or none at all. A few miles south, however, with less rain and more sunshine, a good many of these produce well, among them mango, avocado, fig, chirimoya, and changunga. The southern slope of the plateau below about 4,500 feet is blessed with a nearly perfect climate and, although here the cultivation is limited to a few stream valleys, the variety is great. Around the village of Acahuato, on the southern edge of the plateau, both temperate and tropical vegetables and fruits will thrive. In the *huertas* above the village onions, turnips, cucumbers, squash, and tomatoes flourish along with bananas of many varieties, two or three varieties of figs, avocados, mangos, mameys, oranges, limes, and coffee. The important product of the uncultivated southern plateau regions is turpentine. The largest settlements between Tancitaro and Acahuato are the *resinarías* or turpentine ranches, where the resin tapped in the extensive pine forests is collected and distilled.

Cultivation in the *tierra caliente* is limited to areas under irrigation, and here are extensive plantations of coconut, papaya, lime, orange, avocado, and some grapefruit, although the last named has only recently been introduced. In a few parts of the valley there are large rice fields. Corn is planted but does not produce well because of the very high temperatures. Perhaps the most important industry is cattle raising and some of the largest and finest herds in Mexico are found on the ranches in this valley.

Vegetation

The area under consideration may be divided into the following sections according to the general vegetational composition:

I. *Tropical Region*, the area below 3,000 feet, including the river valley and adjoining slopes up to the edge of the plateau.
   1. Tropical Deciduous Forest, covering the low parts of the valley floor, mostly along or near streams, where plants have access to abundant ground water.
   2. Open Arid Scrub Forest, covering the greater part of the plains of the valley floor.
   3. Dense Arid Scrub Forest, forming a transition belt between the open arid scrub and the mesic deciduous forest.
   4. Homogeneous Scattered Slope Vegetation, on the steep arid slopes between the plains and the edge of the plateau, characterized by a few species of trees in great constancy.
   5. Heterogeneous Canyon and Valley Forest, on the broken slopes and in canyons below the edge of the plateau, consisting in places of nearly open slopes with scattered trees and in other parts of dense scrub forest.

II. *Subtropical Transition Zone.*
   6. This area is entirely covered by open pine forest, and extends from the edge of the plateau north to an altitude of 4,500 feet, although the upper limit is ill-defined. In the pine forests of this region there is a strong intermingling of the tropical element.

III. *High Plateau Temperate Region,* the northern part of the plateau between the altitudes of 4,500 and 7,200 feet.
   7. Upper Plateau Pine Forest, including a great deal of area under cultivation or used for grazing, and no longer forested.
   8. Pedregal Vegetation. The Pedregal is a range of hills two miles south of the village of Tancítaro, extending in an east-west direction across the plateau for about five miles, composed entirely of volcanic rock and harboring a very distinctive vegetation.

IV. *Mountain Temperate Region,* including the mountain proper and beginning at an altitude of about 7,200 feet.
   9. Ridge Forest and Low Mountain Forest, extending up the unbroken slopes and ridges of the mountain to 9,000 feet or higher, a continuation of the pine forests found on the slopes of the plateau.
   10. Valley Forest, found in the deep, humid stream valleys and canyons which lie between the shoulders of the mountain.
      A. Transition to Cloud Forest, extending up the streams from 7,200 to nearly 7,500 feet.
      B. Cloud Forest, extending up the valleys to heights of 9,500 feet, characterized by a very heavy epiphytic vegetation of ferns, bryophytes, and lichens.
   11. High Mountain Area, the area above 9,500 feet, consisting mostly of open pine forest.
      A. Open Pine Forest or Parkland, covering most of the area above 9,500 feet.
      B. Ridge flora, found mostly along the rocky crests of the ridges above 9,500 feet, but including any prominent rocky outcrops in the area.

In considering the individual areas in detail it should be emphasized that there are few species which are limited entirely to one vegetational type. A species may be so widespread as to be characteristic of two or more vegetational types, in which case it is the frequency, size, or form of the plants, as well as the associated species, which give character to the type.

1. TROPICAL DECIDUOUS FOREST

This type of forest is found near streams or in marshy or low-lying areas. Formerly it covered extensive areas of the river valley, but in many areas the land has been cleared for cultivation so that now only solitary trees are left as remnants of the forest which once flourished there. Where this forest is yet undisturbed, many of the trees reach heights of from seventy-five to one hundred feet and have crowns so dense that little sunlight penetrates to the ground; as a result the herbaceous flora is not rich. Characteristic of this type of forest

are many species of trees, all of which are abundant but none of which is predominant as compared to the rest. Some of the more prominent among them are *Trichilia hirta* and *Bursera Simaruba,* conspicuous for their long, slender trunks and smooth, red bark which peels off in papery sheets, giving rise to the name *papelillo,* by which they are both known. Among the figs with buttressed trunks are *Ficus padifolia* (*higuero negro*), *F. mexicana* (*higuero blanco*), and *F. Goldmanii.* Other members of the Moraceae are *Castilla elastica,* widely known as *ule,* and *Brosimum Alicastrum.* Very common and widely distributed is the *capiri, Sideroxylon Capiri,* a large sapotaceous tree with yellow, edible fruits. Another member of the Sapotaceae, commonly cultivated, but growing half wild in places, is the *mamey, Calocarpum mammosum. Diospyros Ebenaster,* known in this region as *sapote negro,* is another common forest tree with edible fruits. Among the Leguminosae, *Enterolobium cyclocarpum* (*parota*), and *Tamarindus indicus* are conspicuous with their wide, feathery crowns. In the more open parts of the forest are the legumes, *Pithecolobium dulce, P. lanceolatum,* and *Inga spuria.* Common species of other families are *Annona reticulata, Forchhammeria pallida, Licania arborea, Calophyllum brasiliense* var. *Rekoi, Gyrocarpus americanus,* and *Tabebuia pentaphylla.*

2. OPEN ARID SCRUB FOREST

This type of vegetation covers by far the greater part of the river valley. Most of the trees in this area do not reach a height of more than forty feet and trees of this height are rather rare, so that the general appearance of the more thickly wooded areas is somewhat like that of chaparral, although the component species are different. In places the thorny thickets are impenetrable. while in others the individual trees and shrubs are so widely spaced that the appearance is that of an open plain with scattered vegetation. In general the scrub forest is characterized by many species in more or less equal abundance, but in places it consists of more or less pure stands. Near the river there are several square miles where there is little but mesquite and *huisache* (*Acacia cymbispina*), and in some of this area there is nothing but *huisache.* East of Apatzingan are arid stretches where little vegetation of any kind is found except isolated trees of *Crescentia alata.* The four species most nearly ubiquitous throughout the scrub forest are mesquite, *huisache, corungoro* (*Zizyphus sonorensis*), and *guayaćan* (*Guaiacum Coulteri*). The latter two grow even in the mesic forest, where they reach a height of forty feet or more. Other species commonly found in much of the arid scrub land are *Caesalpinia platyloba, Diphysa floribunda, Colubrina heteroneura, Malpighia mexicana, Celtis iguanaea, Cyrtocarpa procera, Bursera jorullensis, Jacquinia pungens, Cordia elaeagnoides,* and various species of *Randia.* Somewhat more localized but very abundant are *Acacia macrantha, A. angustissima, A. riparia, Apoplanesia paniculata, Calliandra densifolia, Lysiloma microphyllum, Mimosa distachys, Caesalpinia pulcherrima, Pithecolobium velutinum, Cordia alba, Erythroxylon Pringlei, Malpighia Galeottiana, Bursera grandifolia, Guettarda elliptica, Rauwolfa hirsuta, Achatocarpus nigricans, A. oaxacanus, Manihot tomatophylla, Croton niveus,* and *Capparis angustifolia.*

Cacti are not so prominent or abundant here as in many other similar arid

parts of Mexico, but they do constitute an important element of the vegetation on the arid plains. The two commonest species in the open arid scrub forest are *Pachycereus pecten-aboriginum* and *Acant'iocereus pentagonus*. These are somewhat localized in distribution, being absent from large areas and very abundant in others. Near the Río Tepalcatepec they are found growing in the dense forest close to streams. A large species of *Opuntia* is common on the arid slopes immediately above the valley, and extends down onto the arid plains. This species is very conspicuous locally up to 1,400 feet, but mostly absent above that altitude.

There is a rich herbaceous covering throughout the more open parts of the scrub forest. The lower areas near the river, where there is a good soil, are covered with a turf of *Opizia stolonifera*, but over most of the region grasses are not prominent. *Panicum hirticaule*, *P. fasciculatum*, and *Leptochloa filiformis* are the only species found throughout the plains except along streams or in irrigated fields. The species making up the herbaceous cover in this region are to a great extent vines and spreading herbs of the families Zygophyllaceae, Nyctaginaceae, and Convolvulaceae. *Kallstroemia maxima*, *K. glabrata*, *Okenia hypogaea*, and *Ipomoea pedatisecta* are common on poor and rocky soils throughout the valley, while in cultivated and waste fields *Tribulus cistoides* grows in solid mats. Other herbs found in great abundance are *Jatropha tubulosa*, *J. angustidens*, and *Solanum cornutum*, all of which make collecting in some places very unpleasant because of their spiny, nettle-like characteristics. *Ruellia nudiflora* is probably the most abundant species on the plains. Its purple flowers are conspicuous everywhere, even in mesic woods. *Datura pruinosa* is common but somewhat localized. *Hybanthus oppositifolius* is common everywhere but especially in rocky situations. Further representatives of the Nyctaginaceae are *Boerhaavia erecta* and *B. caribaea*. *Anoda cristata* is the only common mallow. Among other herbs or suffrutescent plants may be mentioned *Melochia pyramidata*, *Trianthema Portulacastrum*, *Martynia annua*, *Solanum deflexum*, *Asclepias curassavica*, *Cassia uniflora*, and *Melampodium americanum*. The curious root parasite, *Lennoa madreporioides*, is common locally throughout the arid parts of the entire tropical region. The supposedly rare *Tradescantia orchidophylloides* is very common locally where there is a fairly good soil and continuous shade.

3. DENSE ARID SCRUB FOREST

There is no sharp line of demarcation between the mesic deciduous forest and the thorny scrub forest of the arid plains on either side. As one travels away from the streams and into well drained soil the persisting mesic forest species become smaller and a mixture of arid forms comes in. Isolated giant trees of fig and *capiri* rise above impenetrable thickets of *Celtis iguanaea*, *Vallesia glabra*, and various species of *Randia*. Still farther from the streams the forest is made up almost entirely of arid species, but the individuals are larger and more numerous, forming dense thickets, often covering large areas. There is no need to enumerate the species in these transition forests, because they are only extensions of the scrub forest which have reached an optimum stage of development as a consequence of having access to more water.

4. HOMOGENEOUS SCATTERED VEGETATION OF THE ARID SLOPES

There are few places where the slopes below the plateau are unbroken by canyons and washes, but between Acahuato and Apatzingan there is an outlier of the plateau on the relatively smooth slopes of which the vegetation is sufficiently distinctive to be mentioned. This outlier is a cone about 3,000 feet high known as Cerro Apatzingan and connected with the plateau by a broad ridge about five hundred feet below the summit. Although there are deep washes and gullies near the top of the mountain, over most of its area the slopes are fairly even and unbroken by rock outcrops. There are only a few species of trees growing here, but these few are abundant and widely and evenly spaced so as to give the appearance from a distance of a regularly planted orchard. This effect is enhanced by the low, spreading, symmetrical crowns of the predominant species, *Pseudosmodingium perniciosum*. Over much of the mountain this species forms nearly pure stands, interspersed occasionally with *Cyrtocarpa procera*. *Comocladia mollissima*, and a few species of *Bursera*. On the lower slopes *Juliania* becomes very prominent and in places nearly supplants *Pseudosmodingium*. It is interesting to note that three of the prominent species of this area belong to the Anacardiaceae, whereas a fourth belongs to the little-known and very localized Julianiaceae. The trees throughout this area are widely enough spaced to permit the development of a continuous stand of grass. The two important species are *Cathestecum erectum* and *Hilaria cenchroides*.

5. HETEROGENEOUS FOREST OF CANYON AND VALLEY

The vegetation of the slopes and canyons below the plateau is even more varied than that of the arid plains. The two areas have many species in common, as is to be expected since the conditions of temperature and rainfall in both are almost exactly the same. Furthermore, rocky ridges extend from below the plateau far out into the plains, and low, rocky ridges and mesas are scattered throughout the plains, all of which bear a vegetation similar to that of the dissected slopes below the plateau, but intergrading with the arid scrub of the plains with respect to many species. No species can be said to be predominant in this type of vegetation, but some families are more heavily represented than others in number of individuals. Among these the Burseraceae are undoubtedly first, with no less than twelve species of the genus *Bursera*, most of which are very common. The Malpighiaceae are second in abundance, although their heaviest distribution is limited to the upper slopes above 2,000 feet. Among the species are *Heteropteris laurifolia*, *H. Palmeri*, *Malpighia mexicana*, and *Byrsonima crassifolia*, known by the name of *changunga* and prized for its fruit. Of these, *Byrsonima crassifolia* is not found at all below 2,000 feet, but above this altitude it becomes in many places the commonest member of the arborescent vegetation. The Anacardiaceae are prominent throughout the area, from the plains to 3,000 feet, with four species which are very common, *Pseudosmodingium perniciosum*, *Cyrtocarpa procera*, *Comocladia mollissima*, and *Spondias purpurea*. Among the other families most heavily represented should be mentioned the Leguminosae, Compositae, Ru-

biaceae, Euphorbiaceae, Verbenaceae, Julianiaceae and Gramineae. Among the legumes are *Apoplanesia paniculata, Caesalpinia pulcherrima, Diphysa floribunda, Erythrina americana, Haematoxylon Brasiletto, Indigofera Palmeri, Lysiloma microphyllum,* and *Piscidia piscipula.* Most of the Compositae are herbs, of which the commonest are *Tridax procumbens, Zinnia maritima,* and several species of *Melampodium* and *Pectis.* These are abundant on open grassy slopes along with the grasses *Cathestecum erectum* and *Hilaria cenchroides,* and the amaranthaceous herb, *Gomphrena dispersa.* The composite shrub, *Porophyllum nutans,* is common throughout the lower slopes and especially on the steep slopes of canyons. Other common composites, mostly of the upper slopes, are *Perymenium Berlandierii, Brickellia paniculata, Salmea Palmeri, Trixis hyposericea, T. longifolia, Zexmenia hispida,* and *Sclerocarpus uniserialis.* The family Rubiaceae is represented on the arid slopes by *Randia echinocarpa, R. Nelsoni,* and *R. laetivirens,* while in the canyons near the streams are found *Guettarda elliptica, Hamelia jorullensis,* and *Cephalanthus salicifolius.* In the Euphorbiaceae *Euphorbia hirta, E. umbellata,* and *E. Schlechtendalii* are common herbs, while *Croton flavescens, Manihot angustiloba, M. mobilis,* and *Phyllanthus micrandrus* are woody forms. *Vitex Hemsleyi* and *V. mollis* of the Verbenaceae are common trees on the upper slopes. The family Julianiaceae is represented by only one species of *Juliania,* but on the slopes bordering the plains this species is often more common than any others. A number of grasses are represented in this vegetational area, although most of them are confined to the stream valleys. Besides *Hilaria cenchroides* and *Cathestecum erectum* on the open slopes are *Bouteloua filiformis, Heteropogon contortus,* and *Panicum hirticaule,* while in the canyons along the streams are found *Arundinella Berteroniana, Eragrostis diffusa, Paspalum plicatulum, P. convexum,* and *P. paniculatum, Digitaria sanguinalis, Aristida ternipes,* and *Hyparrhenia dissoluta.*

Several species not belonging to any of the above mentioned families are characteristic of this type of vegetation. Among them should be mentioned *Thevetia peruviana* var. *pinifolia* and *Plumeria rubra* of the Apocynaceae, *Crescentia alata* of the Bignoniaceae, *Ficus petiolaris* of the Moraceae, and *Ipomoea arborescens* of the Convolvulaceae.

6. SUBTROPICAL TRANSITION FOREST

At an altitude of 3,000 feet, just at the southern edge of the plateau, there is an abrupt change from the arid slopes with their scrubby, scattered vegetation to a forest of tall pines. This forest extends continuously from 3,000 feet to the base of Cerro Tancítaro, and up the mountain in places to 9,000 feet or more. In the area below 5,000 feet *Pinus pseudostrobus* is the dominant, and perhaps the only, species, but above that altitude *P. Ayacahuite* and *P. Montezumae* are found in varying abundance. It is the herbaceous and shrubby flora which largely determines the characters of the various levels of the open pine forest.

Along the lower border of the pine forest are found most of the species common on the upper arid slopes of the tropical region. *Ficus petiolaris, Bursera bicolor, B. fagaroides, B. grandifolia, Byrsonima crassifolia, Vitex Hem-*

sleyi, and *V. mollis* are a few of those species which reach their highest development on the arid slopes just below the pine forest but are also very common in the lower parts of the forest itself. Arborescent or shrubby species reaching their highest development in the lower part of the pine forest between 3,000 and 3,500 feet are *Ficus Pringlei, Annona longiflora, Acacia pennatula, Calliandra callistemon, Brogniartia podalyrioides, Dodonaea viscosa, Psidium Guajava, Cordia brevispicata,* and in the valleys near streams, *Piper acapulcense*. Among the herbs characteristic of this region are *Rhynchosia nigropunctata, Zornia diphylla, Cuphea micropetala, Evolvulus alsinoides, Macromeria exserta, Heliotropium mexicanum, Galeana pratensis, Galinsoga ciliata,* and *Cosmos sulphureus. Tripsacum lanceolatum* is a common grass on well-drained ridges in this area. *Adiantum Shepherdii* is the most abundant fern on open slopes. In the moist soil of rocky ledges along streams are *Galium Aschenbornii, Impatiens Balsamina, Begonia gracilis,* and various species of *Achimenes*. Many species are common throughout the transition area, but especially prominent above 3,500 feet. These include the shrubs *Eriosema grandiflora, Calliandra Houstoniana, Calea urticifolia, Tephrosia cuernavacana, Acalypha subviscida, Stillingia zelayensis, Turnera ulmifolia, Wigandia caracasana, Bouvardia multiflora, Hyptis pectinata,* and *Verbesina Greenmanii,* and the herbs *Milla biflora, Thalictrum Pringlei, Dorstenia Drakena, Heliotropium limbatum, Zinnia angustifolia,* and *Z. linearis. Thalictrum Pringlei* is very common in shady woods and forms solid stands, sometimes to the exclusion of other species. *Dorstenia* is likewise characteristic of the shady parts of the forest, while *Milla biflora, Heliotropium limbatum,* and the two species of *Zinnia* are *common* in open woods and grassy meadows along with the grass, *Bouteloua filiformis*.

Several distinctly tropical trees extend up the streams to an altitude of 4,500 feet or more, but this is exceptional and in general the tropical element has entirely disappeared from the pine forest at this altitude. Above this the character of the vegetation becomes rapidly like that of the high, level plateau just below the mountain. *Pinus Montezumae* and *P. Ayacahuite* become common, and oaks, madroño, and other less frequent trees form a noticeable part of the vegetation.

7. UPPER PLATEAU PINE FOREST

Much of the level part of this region has been cultivated or heavily pastured, so that the vegetation found there is mostly herbaceous. The hills, stream valleys, and barrancas, however, still contain a rich flora of trees and shrubs. On the hills are forests of pine, composed largely of *Pinus Montezumae*, but with a mixture of *P. Ayacahuite* and *P. pseudostrobus*. Intermixed in some places are several species of oak, occasionally forming a conspicuous part of the vegetation. Along the barrancas are *Prunus Capuli* (*capulín*), *Arbutus xalapensis* (*madroño*), *Fraxinus Uhdei, Carpinus caroliniana, Gilibertia arborea,* and *Oreopanax Echinops,* while near the streams are *Tilia occidentalis, Salix Bonplandiana,* and *Crataegus pubescens*. Conspicuous among the trees and low shrubs of this region are *Rubus adenotrichus, Crotalaria vitellina, Acalypha vagans, Croton calvescens, Coriaria thymifolia, Ceanothus coeruleus,*

Lythrum vulneraria, Fuchsia chiapensis, F. fulgens, Tournefortia densiflora, Salvia longispicata, Solanum brachystachys, S. laurifolium, S. Cervantesii, Cestrum thyrsoideum, Castilleja integrifolia, Viburnum Loeseneri, Lobelia laxiflora, Baccharis thesioides, B. ramulosa, and *B. glutinosa.* Noticeable in this group are members of the Solanaceae, which is the most heavily represented family throughout much of this area. The commonest species, however, is a composite, *Baccharis ramulosa,* which is common in fields and open woodlands throughout the plateau between altitudes of 5,000 and 7,200 feet.

The herbaceous vegetation of the high plateau is rich and varied. One of the most characteristic genera is *Cuphea,* with many herbaceous and suffrutescent species, found in both open meadows and dense forests. In pastures and waste fields from 6,000 to 8,000 feet, *Phacelia platycarpa* is often the commonest plant. Mixed with it in the higher part of its range are *Euphorbia campestris, Plantago mexicana, Anagallis arvensis, Oenothera laciniata,* and *Solanum tuberosum.* In the level fields south of the village of Tancítaro, at an altitude of just 6,000 feet, the following species are all abundant: *Polygonum punctatum, Phaseolus heterophyllus, Hypericum uliginosum, Anagallis arvensis, Argemone platyceras, Gaura tripetala, Stachys agraria, Verbena ciliata, V. carolina, Lycianthes somniculenta, Lobelia fenestralis, Erigeron scaposus, Conyza coronopifolia,* and *Aphanostephus ramosissimus,* while on the surrounding open slopes are also *Borreria laevis, B. verticillata, Polygala subalata, Ranunculus Hookeri, Crotalaria sagittalis, Cacalia Palmeri, Heliotropium indicum, Hypoxis decumbens,* and *Habenaria clypeata.* Along the edges of fields and on fences and stone walls are *Ipomoea longipedunculata* and several species of *Phaseolus.* The more open parts of the pine forest are rich in herbaceous species, among which are *Drymaria cordata, Oxalis lanceolata, Geranium aristisepalum, Arracacia vaginata, Scutellaria coerulea, Physalis subintegra, Solanum nigrum, Saracha procumbens, Onosmodium strigosum,* several species of *Viola,* and *Nemastylis versicolor.*

7. PEDREGAL VEGETATION

The vegetation of the volcanic hills known as the Pedregal is very different from that of the surrounding region. From a short distance away they seem to have no vegetation at all and appear as irregular gray ridges of heaped-up boulders. The most striking feature of the area under closer observation is the abundance and variety of ferns. Once actually in the area the observer is struck with the abundance of shrubs not found elsewhere in the vicinity and with the comparative abundance of oaks. The Pedregal in its most elevated parts stands nearly 500 feet above the plateau. It is an irregular series of ridges and valleys, many of them without apparent outlets, in which lie isolated units of vegetation. Each depression or valley is rich in shrubs and small trees. Among them are *Celastrus Pringlei, Photinia mexicana, Clusia Salvinii, Rapanea ferruginea, Rhamnus capreaefolia, Garrya laurifolia,* and *Eupatorium* sp. Along with these are usually a few spreading oaks, which bear a heavy epiphytic vegetation of ferns and orchids. It is interesting that, although epiphytic orchids are common on the plateau and in the mountains east and west of Cerro Tancítaro,

the only locality in which they are found on the plateau to the south is the Pedregal.

The following ferns are represented in our collections from the Pedregal. They do not indicate well the abundance of the pteridophyte flora, because only a very small area was covered, and duplicates of species already collected in other areas were not collected in many cases at all.

1. *Selaginella cuspidata*
2. *Asplenium fragrans*
3. *Asplenium monanthes*
4. *Asplenium praemorsum*
5. *Cheilanthes farinosa*
6. *Cheilanthes intramarginalis*
7. *Cheilanthes lendigera*
8. *Cystopteris fragilis*
9. *Dryopteris patula*
10. *Dryopteris rudis*
11. *Elaphoglossum araneosum*
12. *Elaphoglossum elongatum*
13. *Notholaena candida*
14. *Notholaena nivea*
15. *Pellaea intramarginalis*
16. *Pellaea ternifolia*
17. *Polypodium aureum*
18. *Polypodium furfuraceum*
19. *Polypodium lanceolatum*
20. *Polypodium pectinatum*
21. *Polypodium plebeium*
22. *Vittaria filifolia*
23. *Woodsia mollis*

9. RIDGE FOREST AND LOW MOUNTAIN FOREST

The pine forests of the plateau extend up the slopes of the mountain without much change, where these slopes present no marked differences in environment from the conditions below. Since much of the mountain is cut by deep ravines and canyons, however, only the long ridges between the streams present such conditions. On these ridges the pines form a nearly solid stand up to 9,000 feet or higher, where the slopes are usually broken by cliffs above which the type of vegetation changes abruptly. Above 7,500 or 8,000 feet the pine is mixed with fir (*Abies religiosa*) in varying amounts.

10. VALLEY FOREST

A. *Transition to cloud forest*: This narrow strip lies just above the level where the mountain streams empty onto the plateau. It is an area of dense forest, similar to the cloud forest in many ways, but without the heavy epiphytic flora which characterizes the latter region. The trees are mostly *Pinus Montezumae* and *P. Ayacahuite*, but there are a few species which extend up from the plateau, such as *Quercus laurina* and *Tilia occidentalis*. A common species in this forest is *Alnus glabrata*, which extends from the highest parts of the open plateau along the streams to an altitude of about 8,000 feet in the cloud forest. The forest floor is covered with a dense vegetation of small trees, shrubs, and vines much as in the cloud forest.

B. *Cloud Forest*: The cloud forest as a whole is characterized by a heavy epiphytic growth of ferns, mosses, liverworts and lichens. Along the streams there is an almost impenetrable tangle of shrubs and vines, while on the steep slopes is a dense forest of pine and fir. As this forest extends upward on the diverging slopes it becomes progressively more characteritic of the forest on the ridges by reason of its decreased humidity, resulting from the stronger action of the dessicating winds. The cloud forest presents two distinctly different aspects at different altitudes as follows: (1) The lower stream valleys in which

the predominant trees are *Pinus Montezumae, P. Ayacahuite, Abies religiosa,* and *Alnus glabrata;* (2) The steep upper stretches of the valleys or canyons in which *Abies religiosa* forms almost pure stands.

(1) In the lower, mixed forest are found large trees of *Quercus laurina, Meliosma dentata,* and *Cornus disciflora.* The dogwood is found only above about 8,000 feet, and the *Meliosma* (*mato negro*) is localized in a fairly dense stand between 7,300 and 7,500 feet. *Quercus laurina* is fairly common throughout and reaches its upper limit at nearly 8,400 feet, at which point the pines reach their highest limit in the cloud forest. Among the shrubs which make up the thick undergrowth are *Fuchsia fulgens, F. microphylla, F. Pringlei, Solanum brachystachys, S. Cervantesii, Cestrum Anagyris, Satureja laevigata,* and *Senecio platanifolius.* The last named is the most characteristic shrub of the lower cloud forest and forms solid, impenetrable stands wherever there is a break in the forest cover. Among the vines of this area are *Cuphea Bustamanta, Didymaea alsinoides, Galium mexicanum, Cyclanthera dissecta, C. Langaei, Cuscuta corymbosa* var. *grandiflora,* and *Smilax* sp.

(2) Above 8,200 feet the forest of fir is for the most part so dense that little will grow in the deep shade except the mosses which cover the trunks and lower branches. In the places where shrubs and small trees will grow at all they are usually etiolated and vinelike in form. *Fuchsia microphylla, Cuphea gesneraeflora, Salvia cardinalis, Salix Hartwegi, S. paradoxa, Eupatorium Mairetianum, Arracacia bracteata,* and species of *Quercus, Vernonia* and *Eupatorium* are among the shrubs and small trees found in this forest area. The large grass, *Trisetum Virletii,* is also conspicuous in the fir forest.

A list of the ferns collected in the cloud forest is as follows: *Asplenium fragrans, A. monanthes, Cystopteris fragilis, Notholaena nivea, Polypodium pectinatum, P. plebeium, P. subpetiolatum,* and *Woodsia mollis.* The mosses collected include twenty-three species from nineteen families, are recorded in the List of Genera and Species at the end of this paper. The lichens in the cloud forest are probably the same for the most part as those collected in the open forest just above and are listed in the genera and species collected.

11. HIGH MOUNTAIN AREA

At an altitude of 9,500 feet the dense forest ends abruptly. Above this altitude the slopes of the mountain are covered with an open forest in which there is a rich ground flora of herbs and grasses. This region may be divided into a ridge flora and a valley flora or parkland, as previously indicated. Likewise each of these shows marked differences below and above 10,000 or 10,500 feet. The parkland may be divided as follows: (1) mixed forest parkland, and (2) pine forest parkland.

The mixed forest parkland lies between 9,500 feet and about 10,000 feet. In many ways it is a zone of transition from the cloud forest to the open pine forest above. Scattered stands of fir are common, but are mixed with pine and alder (*Alnus arguta*). The alder forms pure stands of rather open character in many places, especially on moist slopes below cliffs. The trees in this area are heavily laden with epiphytic lichens and mosses, just like those in the cloud

forest. On the alders there is also the fern, *Polypodium polylepis,* which covers the trunk and branches in solid mats.

Above 10,000 feet many of the valleys are wide and cirquelike, with steep sides and gentle slopes below. In these valleys *Pinus Montezumae* and *P. Ayacahuite* reach their best development, attaining a height of one hundred feet or more, and a diameter of about three feet. Even though the forest is open, letting in abundant sunlight, the trunks are straight and branchless to a great height. Below 10,600 feet almost all of the trees are heavily infested with *Arceuthobium vaginatum,* which forms scrubby growths as much as two feet across. There is no shrubby vegetation in these valleys with the exception of *Pernettia ciliata,* which reaches a height along the streams of about two feet. Bunchgrass covers the entire area except a few places where species of *Lupinus* form stands covering several square yards. Growing between the clumps of grass are *Castilleja lithospermoides, Deanea longibracteata, Gnaphalium oxyphyllum, Eryngium bromeliaefolium, Sisyrinchium tenuifolium, Stenanthium frigidum,* and a very abundant species of *Habenaria.* The grasses are for the most part *Agrostis tolucensis, Festuca Rosei, Deschampsia Liebmanniana* and *Trisetum deyeuxioides.*

The ridges between the valleys, with their rocky ledges, cliffs, and steep, moist slopes furnish a very different habitat from that of the valleys. On these ridges between 9,500 and about 10,500 feet flourishes the richest and most varied flora of the mountain. On the moist slopes below cliffs, in addition to scattered stands of pine, alder and fir, are a great variety of shrubs and herbs, many of which are also found on the cliffs and ledges above. Among the shrubs should be listed *Buddleia parviflora, Lopezia pubescens, Holodiscus fissus, Arbutus xalapensis, A. spinulosa, Arctostaphylos angustifolia, A. rupestris, Salvia elegans, S. cardinalis, Castilleja integrifolia, Viburnum microphyllum, Bidens triplinervia, Liabum glabrum, Perymenium Berlandierii, Stevia lucida,* and *Trigonospermum hispidulum.* The variously colored *Pentstemon campanulatus* is one of the most abundant species on these slopes, with the dark red-flowered form predominating. Growing with it are *Macromeria discolor, Oxalis alpina, Cacalia peltata,* and *Piqueria pilosa. Sabazia Liebmannii* is found only in the shade of alder. On the cliffs *Dahlia Merckii* is common, along with the fern, *Asplenium castaneum. Heuchera mexicana* was found growing on moist cliffs just below 10,500 feet. On the crests of the ridges and adjacent well drained slopes are *Cerastium nutans, Oxalis alpina, Geranium Seemanni Castilleja scorzoneraefolia, Pentstemon campanulatus* (pink- and blue-flowered forms), *Stevia jorullensis, S. rhombifolia,* and *Nemastylis brunnea,* as well as various grasses found more abundantly at higher altitudes.

Above 10,500 feet the ridge flora is less varied. With increasing altitude the grasses become more prominent until at this altitude they form the largest part of the herbaceous cover. The chief species are *Festuca amplissima, Muhlenbergia virescens,* and *Agrostis tolucensis.* Other herbs include *Arenaria oresbia, Cerastium nutans, Draba Pringlei, Alchemilla procumbens, Oxalis alpina, Halenia plantaginea, Tauschia nudicaulis, Peperomia umbilicata, Gnaphalium Sprengelii, Hieracium abscissum, Senecio tolucanus, Dahlia Merckii, Bidens triplinervia,* and *Stenanthium frigidum.* The only shrub at this height is *Pernettia ciliata,* growing in thick mats less than one foot in height. On exposed

ledges and cliffs are stunted trees of *Pinus Montezumae* var. *rudis* and *Juniperus tetragona*, the latter being little more than a shrub in most places. For the most part, however, the trees on Cerro Tancítaro show very little the effects of altitude or exposure. The vegetation of the peak itself does not differ from that of the surrounding ridges. There are a few pines which are less dwarfed than some in lower, less favorable situations.

The description thus far applies to the south slopes of the mountain. The north slopes were explored only down to an altitude of 10,500 feet, but in the area above this marked differences could be seen in the composition of the vegetation. First, the flora is richer in number of species on the north side and second, a number of the species growing on both slopes are much more abundant on the north slopes. Some of the species limited to the north side were found in connection with an aquatic habitat different from any on the south side, but others were growing in open parkland on slopes very similar to the same formation on the south side. Among the species apparently absent from the south side are: *Agrostis tacubayensis, Limnia mexicana, Cirsium nivale,* and *Luzula racemosa.* Among the species more abundant on the north slopes are: *Achaetogeron affinis, Lupinus geophilus, L. Aschenbornii, Halenia plantaginea,* and *Trisetum spicatum.*

Discussion

In 1886 Sir Joseph Hooker made the following statement in *Biologia Centrali-Americana,* "No country of equal area presents a richer or more varied vegetation than Mexico. Except perhaps the Javan and the Indian, no tropical flora of great extent is so well explored and so fully represented by collections; and none has been subjected to so searching an analysis, in respect to the correlations of its botanical features and the definition of its botanical regions, as has this flora under Mr. Hemsley's judicious, painstaking, and accurate methods of study." There had been a number of attempts before Hemsley's time to correlate the phytogeographical features of Mexico but, probably because of the very richness and variation of the flora, these attempts were not very successful. The various accounts were not sufficiently similar to make correlation easy and thus present a clear picture of either the vegetation of the entire country or even of the many zones incorporated in any given region. As stated by Ramírez (1898), all these accounts were accurate in one respect, in that they were based on either plant collections or personal observations of vegetation and climate. To ameliorate the situation Ramírez suggested a classification based primarily on climate. By so doing he avoided the mistakes of previous writers, who had not taken into adequate consideration the great climatic differences produced by the peculiar, rough topography of Mexico. He considered temperature and humidity to be the two most important climatic factors. He corrected the previously held idea that the vegetation of the east coast is essentially dissimilar from that of the west coast, pointing out that the climatic conditions with respect to temperature, rainfall, and humidity are very similar along both coasts, with the exception of parts of Baja California. In 1918 Ochoterena presented a classification, which he later amplified (1937), based upon the earlier classification of Ramírez, but considerably

modified. That classification is the most complete which has been made for the country as a whole. It is the purpose of the present paper to give a clear description of the vegetational zones which occur between the peak of Cerro Tancítaro and the Río Tepalcatepec, and to correlate them wherever possible with those described by other authors in other parts of the country.

The account given here is essentially one of altitudinal distribution, in an area where the altitudinal extremes are nearly 11,000 feet. Of course, there are many factors not influenced directly by altitude, or only partially influenced by it, which affect vegetational distribution, and some of them are probably more important, within certain limits, than those which are. Among these are relative humidity and light, influenced greatly by topography, and the edaphic factor of soil. One of the greatest problems in correlating phytogeographic zones with geographic and climatic zones in Mexico is that of determining which factor, or group of factors, is most important in governing the distribution of a given type of vegetation, and what it is that causes the fluctuation of these important factors. Relative humidity is probably the most important factor influencing the prevalence of certain types of plants, yet topography is often as important in controling the relative humidity as is the increased rainfall of higher altitudes. Another factor of great importance is the type of soil or substratum and with it the conditions of drainage. This again is a result of local topography and not of altitude or (to any great extent) of general climatic conditions. Thus we may find widely different environmental conditions in one small local area or almost the same conditions in widely separated parts of the country at greatly varying altitudes. In the region under consideration we find that the presence of the mountain exerts a marked influence over the entire plateau to the south of it, causing increased cloudiness, less sunlight, and lower temperatures, compared with nearby areas at similar altitudes to the east or west. One indication of this is the low extension of the pine forest, which at Acahuato reaches down to 3,000 feet. Throughout much of southern Mexico pine forests do not extend below 6,500 feet, and even around Uruapan, forty or fifty miles to the east, the pine forest is not found much below 6,000 feet. Furthermore, there is often a transition forest of oak, or of oak and pine mixed, between the arid scrub forest and the pine forest, but above Acahuato there is no such transition, the pine forest bordering directly on the arid scrub forest. Possibly as a result of the influence of the mountain, there are other marked differences between the altitudinal location of the various vegetational zones in this region and in other parts of southern Mexico, although several of them correspond closely in composition and character with those described by Ochoterena.

The region here designated as tropical includes formations from both the "región tropical" and the "región templada" of Ochoterena. The Tropical Deciduous Forest of the valley of the Río Tepalcatepec is a part of the same type of tropical forest which extends along both coasts and reaches an altitude of four or five hundred meters in some places on the west coast. The Open Arid Scrub Forest is considered here as tropical, since there are no climatic differences between the areas covered by it and those occupied by the more mesic Tropical Deciduous Forest. It contains some species in common with the region designated by Ochoterena as the "Subregión desierta del Sur," but

it probably should not be classed as a strictly desert area and is probably a variation in many places of the following formation.

Miranda (1941) has described a formation known as *cuajiotal,* found in the "Subregión caliente del sur de la Mesa Central." The term *cuajiotal* is derived from two Nahuatl words meaning "leper tree." It is used to designate a particular type of vegetation composed of trees with scaly bark. There may be a great variation in the proportional numbers of the various species, but the principal genera represented are *Bursera, Pseudosmodingium,* and *Juliania.* In places there are almost pure stands of *Pseudosmodingium perniciosum,* the trees regularly and widely spaced. *Ipomoea arborescens, Ficus petiolaris, Cyrtocarpa procera,* and species of *Plumeria* and *Comocladia* are among the species of secondary importance. Undoubtedly the two formations designated by us as Homogeneous Arid Slope Vegetation and Heterogeneous Canyon and Valley Forest are both types of *cuajiotal.* They are included here in the tropical region because they are not only found under climatic conditions very similar to those of the scrub forest of the plains, but are also continuous with this forest as regards many species. Moreover, the area of *cuajiotal* in our region lies between 1,200 and 3,000 feet, whereas the associations dscribed by Miranda all are found between 865 and 1,880 meters, or, roughly, between 2,800 and 5,000 feet.

The Subtropical Region as delimited here lies entirely within the pine forest. A few miles to the east or west it could probably be extended up to 6,000 feet, because the lower limit of the pine forest becomes progressively higher in either direction, with a corresponding upward extension of tropical forms. In the area under consideration the subtropical region is ill-defined as far as vegetation is concerned, since above 3,500 feet the continuous stand of pine is almost unbroken by other species of trees and shrubs, the best indication of climate being the scattered fig trees and banana plantations in the valleys. The high plateau can not be considered subtropical because the low temperatures, frequent frosts, and even occasional snows of winter have kept out almost entirely any forms from lower regions. This region resembles somewhat in vegetation and climate the valley of Morelia, included by Ochoterena in the "Temperate, Dry Subregion of the Southern Plains of the Central Plateau." His description of this subregion is very brief and he merely makes the statement that the four families, Leguminosae, Gramineae, Cactaceae, and Compositae are abundantly represented. The plateau region around Tancítaro is not rich in grasses and is almost devoid of cacti. It is strikingly characterized by the abundance of arborescent Solanaceae. Although in number of species this family is outnumbered by both the Compositae and Leguminosae, the singular character of the vegetation is a result, to a great extent, of the abundance of solanaceous forms.

Observers who are familiar with the rain forests of Orizaba and of other mountains farther south will realize that the limited cloud forest on Cerro Tancítaro is quite different in some respects from those of other tropical mountains. Many forms, such as tree ferns, and epiphytic orchids and bromeliads, are completely lacking, but the general character of the moist forest with its rich covering of epiphytes is the same. Shreve (1914) described the rain forest of the Blue Mountains in Jamaica as characterized by a great abundance of

epiphytic bryophytes and pteridophytes. Epiphytic orchids were few, but epiphytic bromeliads of a few species were very abundant. Likewise on Cerro Tancítaro the cloud forest is characterized by the great abundance of epiphytic bryophytes and pteridophytes, but epiphytic orchids and bromeliads are absent. Unfortunately we have no way of knowing the exact conditions of moisture in the cloud forest. The relative humidity is very high, near 100% in the summer to judge from the almost continual presence of clouds, but that it remains this high throughout the year is improbable. In considering the character of the cloud forest on Cerro Tancítaro it is necessary to remember that it is at much higher altitude than other such forests in Mexico, and that it probably represents the northernmost outlier of these forests. It is probable that fairly heavy snows fall in these valleys in winter, whereas freezing temperatures are practically unknown in other tropical rainforests.

The summit of Cerro Tancítaro presents no marked change from the lower parts of the mountain which are covered with pine forest, except that there are few young trees and the mature ones are widely spaced. The herbaceous and shrubby vegetation here resembles closely that of other high mountains along the southern edge of the plateau. The slopes north of the peak seem to have a richer flora than those sloping southward. This may be partially explicable on the grounds that they are not so high above the plateau on that side. Merriam (1890) showed that one of the main factors in the distribution of species in the same latitude and altitude was the elevation above base level, that is, the height of a given point above the plane it faces. Thus a mountain, such as Tancítaro, standing on the southern edge of a plateau, will have higher temperatures on the north side than on the south, because the effect of base level is much greater than the effect of slope exposure. The plateau on the south side of Tancítaro is not only lower than that on the north side, but is also negligible in area by comparison, and does not produce the base level effect to any extent.

Summary

During the summers of 1940 and 1941 about sixteen hundred collections of vascular plants, representing one hundred and twenty-four families, were made in the region between Cerro Tancítaro and the Río Tepalcatepec. These collections are fairly complete for the season in which they were taken and are representative of the general character of the vegetation. On the basis of these collections and the climatological data available for the region, as well as from observations made in the field, the region is divided up into vegetational zones and each zone is described in detail. An attempt is made to correlate these zones with similar zones described by other authors for other parts of Mexico.

List of Genera and Species

LICHENES

CLADONIACEAE

Cladonia coccifera (L.) No. 1, pedregal near Tancítaro, 6,000 feet.

PARMELIACEAE

Parmelia cirrhata Fries. No. 2, pedregal near village of Tancítaro, 6,000 feet; Nos. 10, 12, 13; on branches of pine, open parkland, Cerro Tancítaro, 10,500 feet.

Parmelia furfuracea (L.) Ach. Nos. 4, 7, 14; on pine, open parkland above 10,000 feet, Cerro Tancítaro.

Parmelia praesignis Nyl. Nos. 6, 17; on pine and alder, open forest and parkland above 9,500 feet, Cerro Tancítaro.

USNEACEAE

Alectoria ochroleuca (Hoffm.) Mass. No. 9, on pine, open parkland above 10,000 feet, Cerro Tancítaro.

Usnea longissima Ach. Nos. 3, 8, 11, 16; on pine, open parkland, Cerro Tancítaro, above 10,000 feet.

Usnea mexicana Wainio. No. 5, on pine, open parkland above 10,000 feet, Cerro Tancítaro.

Usnea occidentalis Mot. No. 15, on pine, open parkland above 10,000 feet, Cerro Tancítaro.

MUSCI

ANDREAEACEAE

Andreaea turgescens Schp. No. 27, cloud forest, south slope of Cerro Tancítaro in deep canyon, 9,000 feet.

FISSIDENTACEAE

Fissidens asplenoides Hedw. Nos. 4, 28, 33, 34, 49; all growing on the steep, vertical or nearly vertical sides of deep, narrow, moist, shady barrancas near the village of Tancítaro, 6,000 to 7,000 feet.

DICRANACEAE

Campylopus Chrismari (C. M.) Mitt. No. 9, moist soil in cloud forest, Cerro Tancítaro, 9,300 feet.

Symblepharis helicophylla Mont. Nos. 27, 42; on rocks and logs, cloud forest, Cerro Tancítaro, 9,000 feet.

POTTIACEAE

Anoectangium euchloron (Schwaegr.) Mitt. Nos. 4, 8; barranca near the village of Tancítaro, 7,000 feet.

Leptodontium excelsum (Sull.) E. G. Britton; growing on soil, rocks, and tree trunks, cloud forest, Cerro Tancítaro, 9,000 to 9,500 feet.

Leptodontium sulfureum (C. M.) Mitt. No. 45, cloud forest on south side of Cerro Tancítaro, 9,000 feet.

GRIMMIACEAE

Grimmia trichophylla Grev. No. 27, cloud forest, Cerro Tancítaro, 9,000 feet.

Rhacomitrium crispipilum (Tayl.) Jaeg. Nos. 1, 6; on moist rocks, cloud forest, Cerro Tancítaro, 9,300 feet.

BRYACEAE

Bryum sp. No. 48, barranca along road to Los Reyes, near Tancítaro, 6,000 feet.

Rhodobryum Beyrichianum (Hornsch.) Par. No. 22, on rich soil with much organic material, dense forest along stream, Cerro Tancítaro, 8,000 feet.

BARTRAMIACEAE

Breutelia tomentosa (Sw.) Schp. Nos. 5, 15; growing in mats on rocks in cloud forest and above, 8,000 to 10,000 feet, Cerro Tancítaro.

ORTHOTRICHACEAE

Macromitrium lamprocarpum C. M. Nos. 16, 31; growing on trunks of *Quercus decipiens* north of the village of Tancítaro, 7,000 feet.

RHACOPILACEAE

Rhacopilum tomentosum (Hedw.) Brid. No. 3, cloud forest on Cerro Tancítaro, 8,500 feet; Nos. 33, 49; moist sides of barrancas near Tancítaro Village, 6,000 to 7,000 feet.

HEDWIGIACEAE

Hedwigidium imberbe (Sm.) B.S.G. No. 30, tree trunks and branches in cloud forest, Cerro Tancítaro, 8,000 feet.

CRYPHAEACEAE

Cryphaea patens Hornsch. Nos. 3, 40, 44; on tree trunks in cloud forest, from 8,000 to 9,500 feet, Cerro Tancítaro.

METEORIACEAE

Meteorium illecebrum (C. M.) Mitt. No. 17, growing on trunk of oak north of Tancítaro Village, 7,000 feet; Nos. 39, 40; growing on trunks of fir and other trees in cloud forest, from 7,500 to 9,500 feet.

NECKERACEAE

Neckera chlorocaulis C.M. Nos. 3, 26, 29, 39; cloud forest, mostly on fir, 8,000 to 9,500 feet, Cerro Tancítaro.

Porotrichum Leavenworthii E. B. Bartram, sp. nov.

Dioicum ut videtur. Gracile, sat dense caespitosum. Caules secundarii at 4 cm. alti, stipitati, superne irregulariter ramosi, stipite ad 1.5 cm. longo, foliis minutis, plerumque destructis, late triangularibus, breviter acuminatis instructo; ramis erecto-patentibus, subpinnato-ramosis, complanatis, obtusis. Folia late patentia, oblongo-ovata, concava abrupte et breviter acuta, circa 1.6 mm. longa, 0.9 mm. lata; marginibus erectis, superne denticulatis; costa crassa, longe infra apicem folii evanida; cellulae superiores hexagonae, c. 10 μ latae, 15 μ longae, laevissimae, inferiores sensim longiores, infimae lineares, ad 50 μ longae. Seta 9 mm. longa, superne humiliter pustulosa; theca suberecta, ovalis, 2 mm. longa, collo breviusculo; peristomium magnum, pallidum; operculum oblique conico-rostratum, 1.5 mm. longum.

Probably dioicous, no male flowers seen. Slender, pale green plants without lustre, rather densely tufted. Secondary stems stipitate, to 4 cm. high, irregularly branched above; stipe about 1.5 mm. long, remotely and minutely foliate, stipe leaves generally worn and eroded, broadly triangular, short-acuminate; branches erect-spreading, subpinnately rebranched, obtuse, complanate, 2.5-3 mm. wide with leaves. Leaves widely spreading, oblong-ovate, concave, abruptly short-acute, about 1.6 mm. long and 0.9 mm. wide; margin erect, sharply denticulate above; costa strong, ending some distance below the leaf apex; upper cells hexagonal, about 10 μ wide and 15 μ long, nearly isodiametrical, smooth, gradually more elongate below, the basal cells linear, to 50 μ long. Seta slender, 9 mm. long, slightly pustulose near the apex; capsule suberect, ovoid, 2 mm. long, short-necked; peristome large, pale; operculum conic-rostrate, 1.5 mm. long, slightly oblique.

MEXICO: on tree trunks in moist shady places of cloud forest, Cerro Tancítaro, State of Michoacán, alt. 9,000 ft., July 25, 1940, William Leavenworth, no. 18 type. On trees in dense shade and wet place in cloud forest, Cerro Tancítaro, State of Michoacán, alt. 9,000 ft., July 25, 1940, William Leavenworth, no. 32.

Distinct from any of the Mexican or Central American species of the genus with which I am familiar in the slender habit, the short, broad, abruptly pointed leaves of the ultimate branches, the short slender setae, and especially the short, nearly isodiametrical upper leaf cells.

HOOKERIACEAE

Cyclodictyon albicans (Hedw.) Broth. No. 46, in moist barranca near the village of Tancítaro, along the road to Los Reyes, 6,000 feet.

THUIDIACEAE

Thuidium delicatulum (Hedw.) Mitt. No. 14, on marshy ground of meadow near summit of Cerro Tancítaro, growing in a solid mat, like *Sphagnum*, nearly 12,000 feet; No. 35, growing on moist soil under pine on mesa north of Tancítaro Village, 7,000 feet; No. 49, barranca one mile from Tancítaro along trail to Los Reyes, 6,000 feet.

AMBLYSTEGIACEAE

Campylium hispidulum (Brid.) Mitt. var. *Sommerfeltii* (Myr.) Lindb. Nos. 4, 49; barrancas near the village of Tancítaro, 6,000 feet.

BRACHYTHECIACEAE

Brachythecium hastifolium Card. No. 47, dense forest near stream, on the ground, cloud forest, Cerro Tancítaro, 8,000 feet.

Eurhynchium praelongum (Hedw.) Hook. No. 47, on the ground in cloud forest, Cerro Tancítaro, 8,000 feet.

ENTODONTACEAE

Entodon abbreviatus (Bryol. eur.) Jaeg. No. 37, cloud forest, 8,000 feet, Cerro Tancítaro.

HYPNACEAE

Hypnum amabile (Mitt.) Broth. Nos. 23, 25, 27; growing on logs and sheathing tree trunks, cloud forest, Cerro Tancítaro, 8,000 feet.

HYLOCOMIACEAE

Leptohymenium Ehrenbergianum (C.M.) Fleisch. No. 27, cloud forest, Cerro Tancítaro, 8,000 feet.

POLYTRICHACEAE

Polytrichum alpiniforme Card. No. 13, growing in niches in rocky ledges, Cerro Tancítaro, 10,000 feet; No. 24, on rich, moist earth in cloud forest, Cerro Tancítaro, 8,000 feet.

FILICALES

OPHIOGLOSSACEAE

Ophioglossum vulgatum L. No. 1658, open, grassy ridge in open pine forest above Acahuato, 3,200 feet.

SCHIZAEACEAE

Anemia hirsuta (L.) Sw. No. 1574, dry, rocky soil on rocky ledges in canyon below Acahuato, 2,500 feet; No. 1784, common on rocks near stream, open pine woods above Acahuato, 3,500 feet.

SALVINIACEAE

Azolla caroliniana Willd. No. 1476a, open swamp near Hacienda California, 1,200 feet.

POLYPODIACEAE

Acrostichum daneaefolium Langsd. & Fisch. No. 1323, plant up to twelve feet tall, growing in water one to two feet deep in pond at La Majada, 1,200 feet; common in streams and swamps of mesic deciduous forest.

Adiantum convolutum Fourn. No. 1263, common in shaded, moist situations seven miles southwest of Uruapan, 6,000 feet.

Adiantum patens Willd. No. 638, common in brownish-red soil of open pine woods, along trail from Apatzingan to Tancítaro, 5,000 feet; No. 1286, rocky pasture two miles west of Uruapan, 6,000 feet.

Adiantum Shepherdii Hook. No. 1621, open pine forest above Acahuato; common in rich soil on open, rocky slopes, 3,200 feet.

Asplenium castaneum C. & S. No. 1148, rocky ledges, open pine forest, Cerro

Tancítaro, 10,000 feet. No. 1188, Cerro Tancítaro, 10,500 feet; common on rocky ledges above 9,500 feet.

Asplenium concinnum H. & B. No. 1276, rocky pasture two miles west of Uruapan, along trail to Tancítaro, 6,000 feet; very common.

Asplenium cristatum Lam. No. 1087, shaded situation, near bottom of barranca, Cerro San Miguel, 6,700 feet.

Asplenium fragrans Sw. No. 332, epiphyte, growing in moss on tree trunks in dense shade; common in cloud forest, 7,500 feet.

Asplenium monanthes L. Nos. 327, 344, 345; the Pedregal, 6,000 feet and damp canyon on Cerro Tancítaro, 8,000 feet; common on or among rocks in shaded situations from 5,000 to 8,000 feet.

Asplenium praemorsum Sw. Nos. 320, 328; damp rocks in shade, the Pedregal, 6,000 feet. No. 1096, epiphytic on oak, Cerro San Miguel, 6,700 feet.

Bommeria pedata (Sw.) Fourn. No. 1235, *malpais* south of Uruapan, among rocks, common, 5,600 feet.

Cheilanthes angustifolia HBK. No. 653, open pine woods between Tancítaro and Apatzingan, 5,000 feet.

Cheilanthes farinosa Kaulf. Nos. 324, 559; the Pedregal, 6,000 feet; common on rocks in open or in partial shade.

Cheilanthes intramarginalis (Kaulf.) Hook. No. 715, the Pedregal, 6,000 feet, among rocks.

Cheilanthes lendigera (Cav.) Sw. No. 1029, the Pedregal, among rocks, 6,000 feet.

Cheilanthes myriophylla Desv. No. 1236, rocky land similar to the Pedregal, *malpais*, two miles south of Uruapan, 5,600 feet.

Cheilanthes Kaulfussii Kuntze. No. 1285, rocky pasture two miles west of Uruapan, along trail to Tancítaro, 6,000 feet. No. 1790, rocky cliffs at Las Barranquillas, 4,000 feet.

Cystopteris fragilis (L.) Bernh. No. 347, damp soil among rocks, dense forest at 8,000 feet; common.

Doryopteris Skinneri (Hook.) C. Chr. No. 1492, growing in partial shade on or under dry rock ledges, arid lower slopes of Cerro Apatzingan, 2,000 feet. No. 1676, shady bank of barranca, 3,000 feet; one of the few ferns commonly found on the arid slopes below 3,000 feet.

Dryopteris Karwinskyana (Mett.) Ktze. No. 739, open pine forest between Tancítaro and Apatzingan, 5,000 feet.

Dryopteris patens (Sw.) Ktze. No. 654, along stream, trail from Tancítaro to Apatzingan, 5,000 feet. No. 656, barranca, along trail from Tancítaro to Apatzingan, 5,000 feet; large fern, about four feet high, fairly common in moist, shady localities throughout plateau.

Dryopteris patula (Sw.) Underw. No. 321, among rocks, the Pedregal, 6,000 feet; very common in open parts of the Pedregal.

Elaphoglossum araneosum (Eat.) C. Chr. No. 329, among rocks in the Pedregal, partial shade, 6,000 feet.

Elaphoglossum elongatum (Kuntze) Moore. Nos. 567, 717, 1038; among rocks in the Pedregal, 6,000 feet; very common in the Pedregal and other rocky places in protected, shady situations.

Elaphoglossum sp. No. 1190, moist, black soil beside waterfall, Cerro Tancítaro, 10,500 feet; rare.

Notholaena aurea (Poir.) Desv. No. 1233, *malpais* south of Uruapan, 5,600 feet.

Notholaena candida Hook. No. 1028, the Pedregal, 6,000 feet. No. 1713, rocky ledges, arid slopes of canyon, 2,000 feet on Cerro Apatzingan; common in both situations.

Notholaena dealbata Kunze. No. 1271, common in shaded parts of stone walls, west of Uruapan, 6,000 feet.

Notholaena nivea (Poir.) Desv. No. 337, moist rocks beside stream, dense forest, Cerro Tancítaro, 7,500 feet.

Pellaea cordata (Cav.) J. Sm. No. 1234, *malpais* two miles south of Uruapan, 5,600 feet. No. 1275, rocky pasture west of Uruapan, along trail to Tancítaro, 6,000 feet.

Pellaea intramarginalis (Kaulf.) J. Sm. Nos. 1037, 1022; among rocks in the Pedregal, 6,000 feet; common.

Pellaea ovata (Desv.) Weatherby. No. 1003, common on stone walls along trail, near Rancho Santa Catarina, 6,000 feet.

Pellaea sagittata (Cav.) Link. No. 1493, very dry rock ledges, lower slopes of Cerro Apatzingan, 2,000 feet; fairly common.

Pellaea ternifolia (Cav.) Link. No. 309, among rocks in the Pedregal, 6,000 feet.

Plecosorus speciosissimus (A. Br.) Moore. No. 1146, gravelly bank near stream, Cerro Tancítaro, 10,500 feet; common but not abundant in open pine forest above 9,500 feet.

Polypodium angustifolium Sw. No. 1095, epiphytic on oak, Cerro San Miguel, 6,700 feet; rare.

Polypodium angustum (HBK) Liebm. No. 1094, epiphytic on oak, 6,700 feet; rare.

Polypodium aureum L. No. 1040, very common, growing on rocks in the Pedregal, 6,000 feet. No. 1239, rocky land, *malpais*, two miles south of Uruapan, 6,000 feet.

Polypodium furfuraceum S. & C. No. 326, ridge tops, the Pedregal, 6,400 feet. No. 517, epiphytic on oak, two miles north of village, Tancítaro, 6,500 feet. No. 736, epiphytic on oak, Rancho Santa Catarina, 6,000 feet. No. 1237, rocky land west of Uruapan, along trail to Tancítaro, 6,000 feet.

Polypodium heteromorphum Hook. & Grev. No. 1187, moist soil beside waterfall, open pine forest, Cerro Tancítaro, 10,500 feet; not common.

Polypodium lanceolatum L. No. 558, epiphytic on oak, the Pedregal, 6,000 feet.

Polypodium pectinatum L. No. 336, underside of overhanging rock, dense shade, cloud forest, Cerro Tancítaro, 8,000 feet. No. 516a, epiphytic on oak, open fields two miles north of village, Tancítaro, 6,500 feet.

Polypodium plebeium Schlecht. No. 264, epiphytic on oak, open forest north of village, Tancítaro, 6,500 feet. No. 331, the Pedregal, 6,000 feet, not common here. No. 346, on damp soil on rocks, cloud forest, Cerro Tancítaro, 8,000 feet. No. 516, epiphytic on oak, two miles north of village, Tancítaro, 6,500 feet. No. 4041, epiphytic on alder at height of 30 feet, cloud forest, Cerro Tancítaro, 7,800 feet.

Polypodium plesiosorum Kuntze. No. 1791, rocky cliff near Las Barranquillas, 4,500 feet.

Polypodium plumula H. & B. No. 1097, epiphytic on oak, open slope of Cerro San Miguel, 6,700 feet.

Polypodium polylepis Roem. Nos. 1215, 709, epiphytic on alder, 10,000 feet, Cerro Tancítaro; common on *Alnus arguta* between 9,500 and 10,000 feet.

Polypodium subpetiolatum Hook. No. 514, epiphytic on oak, two miles north of village, Tancítaro, 6,500 feet.

Polypodium Rosei Maxon. No. 1240, rocky *malpais* south of Uruapan, 5,600 feet.

Pteridium aquilinum (L.) Kuhn. No. 1106, open pine forest, Cerro San Miguel, 6,700 feet; very common throughout open pine forests from about 3,500 to 7,200 feet.

Pteris cretica L. No. 1069, damp, shady side of barranca, 6,700 feet.

Tectaria trifoliata (L.) Cav. No. 1248, wet soil, dense undergrowth, steep cliffs beside falls, La Tzararacua, seven miles southwest of Uruapan, 6,000 feet.

Vittaria filifolia Fée. No. 1021, growing in caverns formed by rocks, extreme shade, the Pedregal, 6,000 feet; not common.

Woodsia mollis J. Sm. No. 322, on rocks, the Pedregal, 6,000 feet; common. No. 363, stone wall, four miles north of village, Tancítaro, 7,000 feet. No. 714, the Pedregal, 6,000 feet; common in rocky situations and especially on stone walls, 5,000 to 7,200 feet.

Woodwardia radicans Smith. No. 657, barranca, trail from Tancítaro to Apatzingan, 5,000 feet; common fern in moist shady ravines and barrancas up to 6,500 feet.

LYCOPODIALES

SELAGINELLACEAE

Selaginella cuspidata Link. No. 325, on rocks in the Pedregal, 6,000 feet. No. 1238, *malpais* near Uruapan, 5,600 feet. No. 1568, niches in rock beside stream, Acahuato,

2,500 feet. No. 1719, dry rock ledges, Cerro Apatzingan, 2,000 feet. No. 1815, moist soil in rocky canyon above Acahuato, 3,800 feet. Nearly ubiquitous on or among rocks from 2,000 feet or lower to 7,000 feet or higher, very abundant in the Pedregal, where it lines the crevices between rocks.

CONIFERAE

PINACEAE

Abies religiosa (HBK.) S. & C. No. 674, tree 40 feet high, Cerro Tancítaro, 8,400 feet. No. 675, Cerro Tancítaro, 10,000 feet.

Pinus Ayacahuite Ehrenb. *Pino chiño*. No. 272, tree 40 feet high, hill north of village, Tancítaro, 6,500 feet. No. 601, open pasture near the Pedregal, 6,000 feet. No. 1168, tree 25 feet high, Cerro Tancítaro, 10,500 feet.

Pinus Montezumae Lam. *Pino real*. No. 600, tree 60 feet high, cones nearly one foot in length, pasture near the Pedregal, 6,000 feet.

Pinus Montezumae Lam. var. *rudis* Shaw. No. 706, tree about 20 feet high, 10,000 feet; common on exposed ridges above 9,500 feet, Cerro Tancítaro.

Pinus pseudostrobus Lindl. No. 544, tree 50 feet high, pasture near the Pedregal, 6,000 feet; commonest tree from 3,000 feet to about 5,000 feet.

CUPRESSACEAE

Cupressus lusitanica Mill. No. 1223, edge of *malpais* south of Uruapan, 5,600 feet, possibly planted, tree 60 feet high.

Juniperus tetragona Schlecht. No. 672, shrubby tree about 10 feet high, cliff on Cerro Tancítaro, 10,000 feet. No. 1163a, small tree, Cerro Tancítaro, exposed rocky ledge at 10,500 feet.

ANGIOSPERMAE

GRAMINEAE

Aegopogon cenchroides Humb. & Bonpl. Nos. 637, 992; common grass hanging down moist dirt banks beside trails, and in moist soil in woods, collected between 5,000 and 6,000 feet.

Agrostis tacubayensis Fourn. No. 1153, on moist slopes on the north side of Cerro Tancítaro, 11,000 feet; fairly common.

Agrostis tolucensis HBK. Nos. 1112, 1132; common grass in the open pine parkland above 10,000 feet.

Agrostis verticillata Vill. No. 4028, growing in a yard, Tancítaro, 6,000 feet.

Andropogon furcatus Muhl. Nos. 991, 986, 1047; collected along the trail east of Tancítaro, where it is common in partial shade in open pine forest, 6,000 feet.

Andropogon saccharoides Sw. Nos. 1580, 1587; sandbars beside stream in canyon below Acahuato, 2,000 feet; No. 1795, moist soil beside stream, Las Barranquillas, 4,000 feet.

Aristida ternipes Cav. Nos. 619, 1582; common in open pine woods, collected at 5,000 and 6,000 feet.

Arundinella Berteroniana (Schult.) Hitchc. & Chase. No. 1565, in thick mats in shade beside stream, canyon below Acahuato, 2,000 feet.

Bouteloua filiformis (Fourn.) Griff. No. 1607, arid slope near rim of canyon, 2,500 feet; No. 1806, open, rocky soil near stream, Las Barranquillas, 4,000 feet; very common in open pine forest from 3,000 to 4,000 feet.

Bromus laciniatus Beal. Nos. 627, 1078; pine forest, 6,000 to 7,000 feet, not common.

Calamagrostis orizabae Steud. No. 285, open pine parkland at about 11,000 feet; fairly common above 9,500 feet on Cerro Tancítaro.

Cathestecum erectum Vasey & Hack. Nos. 1482, 1582a, 1610; abundant throughout the arid slopes from 1,200 to 3,000 feet.

Cenchrus echinatus L. Nos. 1642, 1767; cultivated fields and sandbars of streams, 3,000 feet.

Chloris virgata Sw. No. 1768, beside trail in open part of pine woods, 3,400 feet.

Cynodon Dactylon (L.) Pers. Nos. 413, 1354; common in moist soil throughout the valley, 1,000 to 1,200 feet.

Dactyloctenium aegyptium (L.) Richt. No. 1328, open situation beside stream, La Majada, west of Apatzingan, 1,200 feet.

Deschampsia Liebmanniana (Fourn.) Hitchc. No. 1175, marshy meadow on north slope of Cerro Tancítaro, 10,500 feet.

Digitaria sanguinalis (L.) Scop. Nos. 1520, 1586a, 1571; arid slopes and waste fields or along streams throughout the *tierra caliente*.

Digitaria velutina (DC.) Hitchc. No. 1794, moist soil beside stream, Las Barranquillas, 4,000 feet.

Echinochloa colonum (L.) Link. Nos. 483, 1458; waste fields of the *tierra caliente*, 1,200 feet.

Eleusine indica (L.) Gaertn. Nos. 456, 563; moist soil beside streams, from 1,000 to 6,000 feet.

Epicampes Emersleyi (Vasey) Hitchc. No. 1289, rocky pasture west of Uruapan, 6,000 feet, common locally.

Eragrostis cilianensis (All.) Link. No. 1659, arid slopes, 2,900 feet.

Eragrostis diffusa Buckl. No. 1569, gravel bars along stream, canyon below Acahuato, 2,000 feet; common.

Eragrostis Elliottii S. Wats. No. 1256, moist, shady cliff near La Cascada de Tzararacua, southwest of Uruapan, 5,000 feet.

Eragrostis intermedia Hitchc. Nos. 990, 1006, 1076; fairly common in open pine woods and pastures from 6,000 to 7,000 feet.

Eragrostis lugens Nees. No. 4027, yard in Tancítaro, 6,000 feet.

Festuca amplissima Rupr. Nos. 704, 1213; common on ridges above 9,500 feet, Cerro Tancítaro, plant about four feet tall.

Festuca Rosei Piper. No. 1127, open pine parkland above 9,500 feet, Cerro Tancítaro.

Festuca tolucensis HBK. No. 1218, rocky ledges on Cerro Tancítaro, 10,000 to 11,000 feet.

Heteropogon contortus (L.) Beauv. No. 1611, common locally on arid slopes at 2,500 feet and also on gravel bars by stream at 2,000 feet.

Heteropogon melanocarpus (Ell.) Benth. No. 1807, in moist soil on side of barranca at Las Barranquillas, 4,000 feet.

Hilaria cenchroides HBK. Nos. 1483, 1500, 1521, 1581; common throughout arid slopes from 1,200 to 3,000 feet and found in open meadows up to 4,000 feet or higher.

Hyparrhenia dissoluta (Nees) Anders. No. 1614, in dense stands on gravel bar near stream, canyon below Acahuato, 2,000 feet, plants four feet high or more.

Ixophorus unisetus (Presl) Schlecht. Nos. 414, 415, 480, 1721; common in fields beside irrigation ditches and in moist soil generally, throughout the river valley and probably up to 3,000 feet.

Lasiacis procerrima (Hack.) Hitchc. No. 1255, common on moist shady cliffs near Cascada de Tzararacua southwest of Uruapan, 5,000 feet.

Lasiacis sp. No. 1272, common in partial shade on stone walls west of Uruapan, 6,000 feet.

Lasiacis sp. Nos. 1674, 1675; common grasses, one about four feet and the other eight to ten feet long, trailing over the edge of a shady barranca, Acahuato, 3,100 feet.

Leptochloa filiformis (Lam.) Beauv. Nos. 500, 1331, 1374; common throughout the river valley in the arid scrub forest and in waste or cultivated fields.

Leptochloa scabra Nees. No. 1330, in water in pool, La Majada, west of Apatzingan, 1,200 feet.

Microchloa Kunthii Desv. No. 1303, common in open pasture west of Uruapan, along trail to Tancítaro, 6,000 feet.

Muhlenbergia breviseta Fourn. No. 987, common locally in well-drained situations along trail between Uruapan and Tancítaro, 6,000 feet.

Muhlenbergia dumosa Scribn. Nos. 985, 1267; abundant locally on the sides of deep, moist barrancas and canyons, along the trail east of Tancítaro, 6,000 feet.

Muhlenbergia Emersleyi Vasey. No. 718, among rocks in the Pedregal, 6,000 feet.

Muhlenbergia virescens (HBK.) Kunth. Nos. 1110, 1217; common on Cerro Tancítaro above 10,000 feet, especially on rocky ridges.

Opizia stolonifera Presl. No. 1748, along trail from Apatzingan to El Capiri on the Río Tepalcatepec, forms a solid ground cover in places where there is a fairly good soil and some moisture.

Oplismenus hirtellus (L.) Beauv. No. 636, in rich, black mud in swamp, 5,000 feet.

Panicum albomaculatum Scribn. Nos. 256, 621, 622, 623, 644; common throughout the pine forest from 5,000 to 6,000 feet.

Panicum fasciculatum Sw. Nos. 443, 1334, 1369, 481; common throughout the river valley, usually in partial shade, 1,000 to 1,200 feet.

Panicum hirticaule Presl. Nos. 1335, 1371, 1453, 1484, 1584a; common throughout the arid parts of the *tierra caliente*.

Panicum parcum Hitchc. & Chase. No. 1484a, arid slope below Acahuato, 2,500 feet.

Panicum purpurascens Raddi. No. 1355, forming a solid stand in a damp field where the forest had been cleared away, La Majada, 1,200 feet.

Panicum reptans L. No. 482, beside irrigation ditch in open field south of Apatzingan, 1,200 feet.

Panicum stramineum Hitchc. & Chase. No. 442a, transition between arid and mesic forest near El Capiri on the Río Tepalcatepec, 1,000 feet.

Paspalum conjugatum Berg. No. 455, near water's edge along the Río Apatzingan south of Apatzingan, 1,200 feet.

Paspalum convexum Flügge. No. 582, fallow field near the Pedregal, 6,000 feet. No. 1585, moist soil near stream, arid canyon below Acahuato, 2,000 feet; common.

Paspalum Humboldtianum Flügge. No. 997, on banks along the trail west of Uruapan, 6,000 feet. No. 1649, common in moist parts of irrigated field above Acahuato, 3,200 feet.

Paspalum Langei (Fourn.) Nash. No. 1336, common along the edge of mesic woods, La Majada, 1,200 feet.

Paspalum paniculatum L. Nos. 442, 1586, 1603; moist soil near streams throughout the tropical region, up to 3,000 feet or higher.

Paspalum plicatulum Michx. No. 1570, beside stream in arid canyon below Acahuato, 2,000 feet; common.

Paspalum squamulatum Fourn. Nos. 382, 620, 647; throughout fields and open forests on the upper part of the plateau, collected at 5,000 and 6,000 feet.

Setaria geniculata (Lam.) Beauv. Nos. 560, 583, 584, 631, 1417, 1584, 1808; common throughout the open pine forest and in fields from 3,000 to 7,000 feet, also found along streams down to the valley.

Setaria Liebmannii Fourn. No. 454, common in moist soil throughout the river valley, often collected by the natives as forage for stock.

Sporobolus Poiretii (R. & S.) Hitchc. No. 562, in rich soil along streams near the Pedregal, 6,000 feet.

Stipa vriescens HBK. No. 1077, on moist banks along trail from Uruapan to Tancítaro, pine forest; fairly common.

Trachypogon Montufari (HBK.) Nees. No. 1284, rocky pasture west of Uruapan, 6,000 feet, not common. No. 1650, in moist parts of irrigated fields above Acahuato, 3,200 feet.

Trisetum deyeuxioides (HBK.) Kunth. Nos. 561, 626, 1141; found on the plateau at 6,000 feet in open pine forest where it is uncommon; on Cerro Tancítaro above 9,500 feet it becomes one of the principal grasses.

Trisetum spicatum (L.) Richt. No. 1159, common on Cerro Tancítaro above 10,500 feet, more abundant on north exposure.

Trisetum Virletii Fourn. No. 994, along trail about three miles west of Uruapan, 6,000 feet. No. 1122, six feet or more in height, Cerro Tancítaro, fir forest, 9,400 feet.

Tripsacum lanceolatum Rupr. Nos. 1638, 1643, 1311; well-drained ridges and rocky slopes from 3,000 to 4,000 feet; fairly common in open pine forest above Acahuato.

Zeugites Pringlei Scribn. Nos. 988, 1060; barranca four miles east of Tancítaro, very shady, moist location; No. 1086, barranca and adjacent pine forest on Cerro San Miguel, 6,700 feet, a very localized species but extremely abundant where found.

CYPERACEAE

Bulbostylis junciformis (HBK.) Clarke. No. 1039, among rocks, the Pedregal, 6,000 feet.

Carex festivella Mackenzie. No. 1171, common in moist meadow, north slope of Cerro Tancítaro, 10,500 feet.

Carex psilocarpa Steud. No. 1170, moist meadow, north slope of Cerro Tancítaro, 10,500 feet.

Cyperus caracasanus Kunth. No. 591, moist soil in open meadow near the Pedregal, 6,000 feet.

Cyperus cyperoides (L.) Britton. No. 1062, along trail east of Tancítaro, grassy pasture, 6,000 feet.

Cyperus divergens HBK. No. 298, waste field west of Tancítaro, 6,000 feet.

Cyperus ferax L. Rich. No. 1066, back yard in Tancítaro, moist soil, 6,000 feet.

Cyperus flavus (Vahl) Nees. No. 1061, grassy field along trail east of Tancítaro, 6,000 feet.

Cyperus incompletus (Jacq.) Link. No. 716, among rocks, the Pedregal, 6,000 feet.

Cyperus ochraceus Vahl. No. 1357, grassy field, moist soil, La Majada, 1,200 feet.

Cyperus seslerioides HBK. No. 1671, among rocks, open pine forest, 3,200 feet.

Eleocharis acicularis (L.) R. & S. No. 1221, submerged in water 4-6 inches deep, pond in marshy meadow, north slope of Cerro Tancítaro, 10,500 feet.

Fimbristylis complanata (Retz.) Link. No. 1326, in water, marshy meadow, north slope of Cerro Tancítaro, 10,500 feet.

Kyllinga brevifolia Rottb. No. 376, waste field, one mile south of village, Tancítaro, 6,000 feet; No. 1812, along stream on rocky soil above Acahuato, 3,800 feet; common in open fields from 3,000 to 7,200 feet.

PALMACEAE

Chamaedorea Pringlei Wats. No. 1262, wet cliff near falls seven miles southwest of Uruapan, 6,000 feet.

ARACEAE

Pistia Stratiotes L. No. 1476, shallow, open swamp near Hacienda California, 1,200 feet.

LEMNACEAE

Spirodela polyrhiza (L.) Schleid. No. 1476b, open swamp near Hacienda California, with *Pistia*, *Azolla*, etc.

ERIOCAULACEAE

Eriocaulon Benthami Kunth. No. 659, shaded, swampy ground, open pine forest, trail from Tancítaro to Apatzingan, 5,000 feet.

COMMELINACEAE

Commelina coelestis Willd. No. 307, flowers blue, among rocks in the Pedregal, 6,000 feet.

Commelina erecta L. No. 1527, shaded places between rocks, canyon between Apatzingan and Acahuato, 2,000 feet, common; No. 1662, among rocks, open pine forest, 3,200 feet.

Tinantia erecta (Jacq.) Schlecht. No. 726, cloud forest, Cerro Tancítaro, 7,500 feet; rare.

Tradescantia crassifolia Cav. No. 1280, rocky meadow west of Uruapan, 6,000 feet.

Tradescantia orchidophylloides Bullock. No. 405, moist soil in dense shade, bank of Río Apatzingan, two miles south of town of Apatzingan; No. 1373, arid scrub forest

four miles west of Apatzingan, rich soil in shaded situations: abundant locally, 1,200 feet.

BROMELIACEAE

Bromelia mucronata Mez. No. 1451, plants four feet high, arid thorn forest near Hacienda California, 1,200 feet.

Pitcairnia Schiedeana Baker. No. 1027, growing among rocks, the Pedregal, not common, 6,000 feet.

Tillandsia recurvata L. No. 1231, epiphytic on small trees, *malpais* south of Uruapan, 5,600 feet.

Tillandsia usneoides L. No. 735, epiphytic on oak near Rancho Santa Catarina, 6,000 feet; abundant very locally about this altitude.

PONTEDERIACEAE

Eichhornia azurea (Sw.) Kunth. No. 411, irrigation ditch, pasture near Apatzingan, 1,200 feet. No. 1323a, shaded swamp, La Majada, 1,200 feet; common in ponds and streams throughout the river valley.

JUNCACEAE

Luzula gigantea Desv. Nos. 1130a, 1139, moist soil beside streams, open pine forest above 10,500 feet, Cerro Tancítaro.

Lazula racemosa Desv. Nos. 1158, 1174a; moist meadows, north slopes of Cerro Tancítaro, 10,500 feet to summit, common.

LILIACEAE

Allium glandulosum Link & Otto. No. 1302, flowers purple, pasture west of Uruapan, 6,000 feet.

Bessera elegans Schult. No. 501, lower slopes of Cerro Apatzingan, 2,000 feet; fairly common between 2,000 and 3,500 feet.

Calochortus barbatus (HBK.) Painter. No. 734, trail from Tancítaro to Uruapan, steep slope in pine-oak forest, 6,000 feet.

Echeandia Pringlei Greenm. No. 1508, flowers white, Cerro Apatzingan, arid slopes, 2,000 feet; common on arid slopes from 1,200 to 3,500 feet.

Milla biflora Cav. No. 1781, flowers white, open pine forest, 4,000 feet; very common in open pine forest between 3,500 and 4,500 feet.

Nothoscordum fragrans (Vent.) Kunth. No. 4002, moist soil, open, grassy hillside near the Pedregal, 6,000 feet.

Stenanthium frigidum (S. & C.) Kunth. No. 1135, steep slopes in open pine forest, Cerro Tancítaro, 10,500 feet; common above 10,000 feet, especially along ridges or on steep, rocky slopes on the north side of the mountain.

SMILACACEAE

Smilax moranensis M. & G. Nos. 1073, 1092, Cerro San Miguel, 6,700 feet, climbing over trees and shrubs in open forest and shady barranca; common.

DIOSCOREACEAE

Dioscorea capillaris Hemsl. No. 1685, vine twining on shrubs in open fields on edge of pine forest, 3,200 feet.

Dioscorea lobata Uline. No. 1469, vine climbing over shrubs in arid scrub forest west of La Majada, 1,200 feet; No. 1539, vine creeping over low vegetation, arid slope, side of canyon below Acahuato, 2,500 feet.

Dioscorea militaris Rob. No. 1732, vine, arid slopes of Cerro Apatzingan, 2,500 feet; not common.

Dioscorea minima Rob. & Seat. No. 1050, common in grazed, grassy pasture land, four miles east of Tancítaro, 6,000 feet.

Dioscorea polygonoides H. & B. No. 1715, vine twining over low shrubs, lower slopes of Cerro Apatzingan, 2,000 feet.

Dioscorea sp. No. 1020, vine, climbing over trees and shrubs, the Pedregal; common.

AMARYLLIDACEAE

Agave brachystachys Cav. No. 652, open pine woods, 5,000 feet; very uncommon in this area.

Agave undulata Klotsch. No. 1601, arid side of canyon below Acahuato, 2,500 feet.

Crinum erubescens Soland. No. 1327, growing in water at edge of pool, La Majada, 1,200 feet.

Hypoxis decumbens L. No. 301, waste field west of village, Tancítaro, 6,000 feet; No. 537, two miles north of village, Tancítaro, 6,500 feet; No. 541, growing in open pasture, two miles north of Tancítaro; common in open pine woods and in pastures.

Pancratium Leavenworthii Standl. & Steyerm., sp. nov.

Bulbus ovoideus, ca. 4 cm. longus et 2.5 cm. latus, in collum brevem crassum contractus; folia longipetiolata, in sicco membranacea, petiolo gracillimo ca. 19 cm. longo, prope mediam vix 2 mm. lato; lamina lanceolato-oblonga 15 cm. longa, 3 cm. lata, acuta vel acuminata, basi acuminata sed abrupte in petiolum contracta, subtus paullo pallidior; scapus ca. 30 cm. altus, prope mediam vix 3 mm. crassus, biflorus, floribus sessilibus; valvae spathae lanceolatae scariosae, 4 cm. longae, attenuatae, tenuiter nervosae; ovarium ca. 8 mm. longum; perianthium album, tubo gracillimo, 7 cm. longo, 1.3 mm. lato, sursum vix dilatato, segmentis linearibus tubum aequantibus, paullo ultra 1 mm. latis; filamenta gracillima, segmentis breviora; antherae apice appendiculatae, appendice excurvo 3.5 mm. longo; cupula staminalis angusta, 15 mm. longa, apice 5 mm. lata.

MEXICO: Michoacán: Open grassy pastures or in part or deep shade, commonest on dirt banks among pines, common very locally, the flowers white, road from Tancítaro to Apatzingan, alt. 4,500 ft., August 17, 1940, William C. Leavenworth 651 (type in Herb. Chicago Nat. Hist. Mus.).

With the present unsettled status of most of the species of this genus, it is scarcely advisable to describe new species of *Pancratium*, but the present plant appears to be a distinct and somewhat unusual entity that we are unable to place among published species. It is noteworthy for the small leaves, the blade relatively broad and abruptly contracted into the very long petiole, and for the rather small flowers with an exceptionally small and narrow staminal cup.

Pancratium litorale Jacq. No. 1319, mud at edge of pool, mesic forest, La Majada, 1,200 feet. No. 1422, damp ravine in open pine forest, La Cañada, 4,000 feet.

IRIDACEAE

Nemastylis brunnea Wats. No. 680, rocky ridges, Cerro Tancítaro, 10,000 feet; very common locally.

Nemastylis tenuis (Baker) B. & H. No. 1265, flowers dark blue, near falls seven miles southwest of Uruapan, 6,000 feet; No. 1301, flowers purple, rocky pasture west of Uruapan, along road to Tancítaro, 6,000 feet.

Nemastylis versicolor Wats. No. 610, open pine forest, along trail from Tancítaro to Apatzingan, 5,000 feet; very common from 4,500 to 8,500 feet or higher.

Sisyrinchium iridifolium HBK. No. 305, flowers yellow, among rocks in rich loam, the Pedregal, 6,000 feet.

Sisyrinchium tenuifolium H. & B. Nos. 1181, 1182, open pine forest, 10,500 feet, Cerro Tancítaro. There seem to be two distinct size forms, both very common.

Sisyrinchium Palmeri Greenm. No. 681, flowers yellow, open pine forest, 10,000 feet.

ORCHIDACEAE

Arethusa grandiflora Wats. No. 570, flowers pink, among rocks in the Pedregal, 6,000 feet.

Bletia campanulata Llave & Lex. No. 390, open pine forest, 5,000 feet.

Bletia purpurea (Lam.) DC. No. 1799, flowers yellow to brown, rocky places near stream, Las Barranquillas, 4,000 feet.

Bletia reflexa Lindl. No. 299, waste field west of Tancítaro, 6,000 feet; No. 306, the Pedregal, soil among rocks, 6,000 feet; No. 732, near Santa Catarina, trail from Tancítaro to Uruapan, 6,000 feet; fairly common throughout open pine forest from 4,000 to 7,000 feet, but never abundant.

Epidendrum chondylobolbon Rich. & Gal. No. 1017, epiphytic on oak, corolla white striped with purple, trail from Uruapan to Tancítaro, 6,000 feet; not common.

Epindendrum venosum Lindl. No. 1016, epiphytic on oak, flowers yellow and white, sweet-scented, trail from Uruapan to Tancítaro, 6,000 feet; localized but very abundant where found.

Epidendrum sp. No. 572, epiphytic on oak, the Pedregal, 6,000 feet.

Govenia superba (Llave & Lex.) Lindl. No. 1058, among rocks, shady side of barranca, four miles east of Tancítaro, 6,000 feet.

Habenaria clypeata Lindl. No. 528, flowers white, open pasture above Tancítaro village, 6,500 feet; very common in woods and open fields over much of the plateau above 7,000 feet.

Habenaria macroceratitis Willd. No. 738, flowers green, abundant on red clay bank near Rancho Santa Catarina, 6,000 feet; very localized.

Habenaria limosa (Lindl.) Hemsl. No. 1142, flowers green, open pine forest, Cerro Tancítaro, 10,500 feet; very common in moist meadows and slopes above 10,000 feet.

Malaxis carnosa (HBK.) Schweinfurth. No. 996, open pine forest west of Uruapan, about 6,000 feet; No. 1014, in moist soil in open situation, bank of deep barranca about two miles south of Tancítaro, 6,000 feet.

Malaxis fastigiata (Rchb.) Kuntze. No. 304, the Pedregal, rich soil in woods, 6,000 feet; Nos. 1,015, 4,000; pine forest near the Pedregal, rich soil, 6,000 feet; No. 1777, open pine forest above Acahuato, 4,000 feet; flowers green or pale yellow, fairly common in rich soil from 3,000 to 8,000 feet.

Odontoglossum madrense Rchb. f. No. 1004, epiphytic on oak near Santa Catarina, common locally, 6,000 feet.

Pleurothallis longispicata L. O. Williams. No. 1005, upon oak, near Rancho Santa Catarina, 6,000 feet.

PIPERACEAE

Peperomia coalcomana Trel. No. 4042, 30 feet above ground on alder, cloud forest, 7,800 feet, Cerro Tancítaro.

Peperomia edulis Miq. No. 557a, the Pedregal, in mats of moss on trees and rocks, common, 6,000 feet.

Peperomia galioides HBK. Nos. 557, 1036; the Pedregal, in mats of moss on trees and rocks, common, 6,000 feet.

Peperomia umbilicata R. & P. Nos. 4019, 1161, in moss on moist rocks, Cerro Tancítaro, 10,500 feet; common throughout the cloud forest and up to 11,000 feet.

Piper acapulcense Trel. No. 1828, shrub twelve feet high, beside stream, Acahuato, 3,000 feet.

Piper Berlandieri C. DC. No. 1056, shrub six feet high, deep barranca four miles east of Tancítaro, 6,000 feet.

SALICACEAE

Salix Bonplandiana HBK. No. 579, tree fifty feet high, flood plain of small stream near the Pedregal; rare.

Salix Hartwegii Benth. No. 1196, tree fifteen feet high, dense forest, Cerro Tancítaro, 9,000 feet; rare.

Salix paradoxa HBK. No. 1162, tree twenty-five feet high, open pine forest beside stream, 10,300 feet, Cerro Tancítaro; No. 1197, shrub seven feet high, dense forest, 9,000 feet; rare.

GARRYACEAE

Garrya longifolia Rose. No. 571, tree ten to twenty feet high, the Pedregal, 6,000 feet.

Garrya laurifolia Hartw. No. 1045, shrub six to seven feet high, quite common in the Pedregal.

JULIANIACEAE

Juliania adstringens Schlecht. Nos. 1497a and b, tree ten to fifteen feet high, sometimes thirty feet, flowers dioecious, bark with milky latex; very abundant on lower slopes of Cerro Apatzingan from 1,200 to 1,400 feet, but no higher.

FAGACEAE

Quercus acapulcensis Trel. No. 1104, tree 15 to 20 feet high, open pasture on lower slopes of Cerro San Miguel, 6,400 feet.

Quercus Bourgaei Oerst. No. 1074, tree 40 feet high, mixed forest along barranca, Cerro San Miguel, 6,700 feet; No. 1195, tree 15 feet high, dense fir forest at 9,000 feet, Cerro Tancítaro.

Quercus calophylla Cham. & Schlecht. Nos. 1098, 1102; trees 30 and 60 feet tall, edge of barranca, Cerro San Miguel, 6,700 feet.

Quercus candicans Née. No. 546, tree 70 feet high, 3 feet through (dbh), beside stream near the Pedregal, 6,000 feet.

Quercus castanea Née. No. 543, tree between 40 and 60 feet in height, beside stream near the Pedregal, 6,000 feet.

Quercus crassifolia Humb. & Bonpl. No. 4008, tree 20 to 30 feet high, in the Pedregal.

Quercus decipiens Mart. Nos. 261, 514a; tree up to 35 feet or more in height, common between 6,000 and 7,000 feet on the plateau, often along barrancas.

Quercus laurina Humb. & Bonpl. Nos. 342, 362, 701; tree 40 to 60 feet high, dense forest along streams, Cerro Tancítaro, from 7,500 to 9,000 feet.

Quercus michoacana Trel. No. 1099, tree 30 feet high, edge of barranca, Cerro San Miguel, 6,700 feet.

Quercus macrophylla Née. No. 1270, tree six feet high, usually somewhat taller, near Cascada de Tzararacua, southwest of Uruapan, on open, well-drained slopes, common, 6,000 feet.

Quercus sp. No. 1044, tree ten feet high, spreading to cover an area 20 feet or more across, among rocks, Pedregal, 6,000 feet, common.

BETULACEAE

Alnus arguta (Schlecht.) Spach. No. 699, tree thirty-five feet high, Cerro Tancítaro, 10,000 feet; No. 1191, beside stream, cloud forest, Cerro Tancítaro, 7,700 feet; this tree is common between 9,500 and 10,000 feet, where it forms extensive open stands on steep, wet slopes.

Alnus glabrata Fern. Nos. 339, 343; tree forty to fifty feet high, cloud forest beside stream, Cerro Tancítaro, 8,000 feet; common tree between 7,000 and 8,200 feet.

Alnus jorullensis HBK. No. 1206a; tree thirty feet high, mixed parkland, Cerro Tancítaro, 10,000 feet.

Carpinus caroliniana Walt. Nos. 1070, 1103; Cerro San Miguel, 6,700 feet; common in barrancas and on hillsides about this altitude, forms solid stands, reaches height of sixty feet or more.

URTICACEAE

Pouzolzia Palmeri Wats. No. 1701, shrub four feet high, pine forest above Acahuato, 3,200 feet.

ULMACEAE

Celtis iguanaea (Jacq.) Sarg. No. 1438, tree fifteen feet high; No. 1473, fifteen to twenty feet high, shrublike; arid thorn forest near Hacienda California, 1,200 feet, forms impenetrable thickets.

MORACEAE

Brosimum Alicastrum Sw. No. 1472, tree eighty to ninety feet high, near stream but growing in arid soil, eight miles west of Apatzingan, 1,200 feet.

Castilla elastica Cerv. *Ule*. No. 1449, tree fifty feet high, mesic forest near Hacienda California, 1,200 feet.

Dorstenia Drakena L. No. 388, open pine woods, 4,500 feet; No. 1316, mesic forest on damp soil, La Majada, 1,200 feet; common in mesic woods from 1,000 to 4,500 feet.

Ficus cotinifolia HBK. No. 1386, tree thirty feet high, arid scrub forest four miles west of Apatzingan, 1,200 feet.

Ficus Goldmanii Standl. *Higuera negra*. No. 1348, tree ninety feet high, mesic forest near La Majada, 1,200 feet.

Ficus lapathifolia (Liebm.) Miq. Nos. 1010, 1011, tree twenty to thirty feet high, rocky pasture west of Uruapan, 6,000 feet.

Ficus mexicana Miq. *Higuera blanca*. No. 1338, tree seventy feet high, mesic forest, La Majada, 1,200 feet; No. 1430, tree one hundred feet or more, swampy area near Hacienda California, 1,200 feet; common tree in mesic forest.

Ficus padifolia HBK. *Camuchin*. No. 1343, tree seventy feet high, La Majada; No. 1439, tree eighty feet high, mesic forest near La Majada; No. 1559, tree forty feet high, growing around other trees, arid plains west of Apatzingan, 1,200 feet; commonest fig in the tropical deciduous forest.

Ficus petiolaris HBK. No. 1594, low, gnarled tree fifteen feet high, bark greenish-white, smooth, edge of canyon, arid slopes below Acahuato, 2,500 feet; characteristic tree of this area from 2,000 to 3,500 feet.

Ficus Pringlei Wats. Nos. 1511, 1626, 1682, 1691, 1830; tree ten to thirty-five feet high, common on arid slopes from 2,000 to 3,000 feet and very common in the open pine forest between 3,000 and 3,500 feet.

LORANTHACEAE

Arceuthobium vaginatum (HBK.) Eichl. Nos. 710, 1126, common on pine between 9,500 and 10,500 feet.

Psittacanthus calyculatus (DC.) Don. No. 255, parasitic on *Prunus Capuli*, near village, Tancítaro, 6,000 feet; common parasite on angiospermous trees, 5,000 to 7,000 feet.

Psittacanthus Schiedeanus (Cham. & Schlecht.) Blume. No. 1688, parasitic on *Pseudosmodingium*, arid slope below Acahuato, 3,000 feet; not common.

Struthanthus densiflorus (Benth.) Standl. No. 1043, parasitic on *Prunus Capuli*, near Tancítaro village, 6,000 feet.

Struthanthus microphyllus (HBK.) Don. No. 340, on *Alnus glabrata*, cloud forest, Cerro Tancítaro, 7,800 feet; No. 1410, on *Guettarda elliptica*, arid plains west of Apatzingan, 1,200 feet; No. 1513, growing on *Thevetia peruviana*, var. *pinifolia*, 1,300 feet.

Struthanthus venetus (HBK.) Blume. No. 1656, long, tangled vine, climbing on trees and shrubs, open pine forest above Acahuato, 3,200 feet.

ARISTOLOCHIACEAE

Aristolochia variifolia Duch. No. 449, vine growing in shady, mesic woods near stream one mile south of Apatzingan, 1,200 feet.

Aristolochia Pringlei Rose. No. 1009, climbing over low bushes west of Uruapan, along trail, open pine forest, 6,000 feet.

Aristolochia foetida HBK. No. 1317, mesic woods, La Majada; very common vine of mesic forest, 1,200 feet.

Aristolochia pentandra Jacq. No. 1496, vine, climbing over low shrubs or prostrate, flowers dark red and green, common.

POLYGONACEAE

Rumex mexicanus Meissn. No. 253, waste field, bank of barranca, near Tancítaro village, 6,000 feet.

Polygonum punctatum Ell. No. 368, common along edges of fields on bare soil, near Tancítaro, 6,000 feet; No. 1698, beside irrigation ditch above Acahuato, 3,200 feet.

Podopterus mexicanus Humb. & Bonpl. No. 1743, tree twenty feet high, along trail from Apatzingan to El Capiri, arid plain, 1,100 feet.

AMARANTHACEAE

Amaranthus Berlandieri (Moq.) Uline & Bray. No. 433, waste fields and dry, open plains around Apatzingan; very common.

Gomphrena decumbens Jacq. No. 1297, flowers pink, pasture west of Uruapan, 6,000 feet.

Gomphrena dispersa Standl. No. 1487, dry lower slopes of Cerro Apatzingan, 1,300 feet; common on arid slopes from 1,200 to 3,000 feet.

NYCTAGINACEAE

Boerhaavia caribaea Jacq. No. 1389, flowers magenta, sandy soil in dry arroyo, arid scrub forest west of Apatzingan, 1,200 feet.

Boerhaavia erecta L. No. 406, waste fields and dry, open slopes, flowers white or pinkish; very common herb throughout tropical zone.

Mirabilis Pringlei Weatherby. No. 1467, arid plains west of Apatzingan; not common except locally.

Okenia hypogaea Schlecht. & Cham. Nos. 428a, 438, 465, 1404, 1481, arid plains and waste fields around Apatzingan; one of the commonest herbs throughout the flat, arid parts of the *tierra caliente*.

PHYTOLACCACEAE

Achatocarpus nigricans Triana. *Huasicuco*. No. 430, tree fifteen to twenty feet high, arid plains near El Capiri, Río Tepalcatepec, 1,000 feet.

Achatocarpus oaxacanus Standl. No. 1746, tree ten feet high, profusely branched, spreading and twining, road to El Capiri, arid plains, 1,100 feet.

Petiveria alliacea L. No. 441, herb twenty to thirty inches high, semi-arid transition zone near Río San Antonio at junction with Río Tepalcatepec, 1,000 feet.

Stegnosperma scandens (Lunan) Standl. No. 1394, vine growing on trees, edge of dry arroyo, arid scrub forest west of Apatzingan, 1,200 feet.

AIZOACEAE

Trianthema Portulacastrum L. No. 436, arid scrub forest near Río Tepalcatepec, 1,000 feet; No. 1407, arid plains near La Majada, 1,200 feet; common herb of arid plains and waste lands of river valley.

PORTULACACEAE

Limnia mexicana Rydb. No. 708, marshy meadow, Cerro Tancítaro, 11,200 feet; apparently rare.

Talinum triangulare (Jacq.) Willd. No. 434, partial shade in arid scrub forest near El Capiri, Río Tepalcatepec, 1,000 feet; common.

CARYOPHYLLACEAE

Arenaria oresbia Greenm. Nos. 280, 1140, 1145, 1150, open pine forest, Cerro Tancítaro; common on moist rocky ledges from 9,500 feet to the summit.

Arenaria lanuginosa (Michx.) Rohrb. No. 1083, vine, common in moist soil in deep barranca, Cerro San Miguel.

Arenaria moehringioides (M. & S.) B. & H. No. 1283, rocky pasture west of Uruapan, 6,000 feet; usually growing in underbrush where other plants support it.

Arenaria reptans Hemsl. Nos. 1111, 1113, open grassy slopes above 9,500 feet, Cerro Tancítaro.

Cerastium nutans Raf. Nos. 689, 1119, open pine forest, partial shade, very common; No. 1079, Cerro San Miguel, 6,700 feet, open pine woods; No. 4039, cloud forest, Cerro Tancítaro, 8,000 feet.

Cerastium molle Benth. No. 278, open pine forest, Cerro Tancítaro, 11,000 feet.

Drymaria cordata (L.) Willd. No. 595, moist, shaded situation beside stone wall, near the Pedregal, 6,000 feet.

Drymaria villosa Schlecht. & Cham. No. 525, growing in water in aqueduct, above Tancítaro, 6,300 feet; No. 1293, open rocky pasture west of Uruapan, 6,000 feet; No. 1295, shade of stone walls, west of Uruapan, common, 6,000 feet.

RANUNCULACEAE

Ranunculus Donianus Pritzel. No. 1169, marshy meadow, 10,500 feet, Cerro Tancítaro.

Ranunculus Hookeri Schlecht. Nos. 251, 257, 4030; near Tancítaro, 6,000 feet; common in open throughout plateau and into cloud forest above 8,000 feet.

Thalictrum guatemalense C. DC. & Rose. No. 1232, *malpais* south of Uruapan; growing among rocks.

Thalictrum Pringlei Wats. No. 989, trail from Uruapan to Tancítaro, near Santa Catarina, 6,000 feet; No. 395, open pine forest above Acahuato, 4,500 feet; No. 1823, common in open pine forest above Acahuato, sometimes in pure stands, 3,500 to 4,000 feet.

Thalictrum pudicum Standl. & Boivin. Rhodora **46**:434. 1944. No. 1013, open mossy ground, edge of deep barranca, near the Pedregal, 6,000 feet; rare; this collection the type of the new species.

Thalictrum sessilifolium Boivin. No. 250, west of Tancítaro, on edge of arroyo, 6,600 feet; herb 5 to 7 feet high.

MENISPERMACEAE

Cissampelos Pareira L. No. 1266, near falls seven miles southwest of Uruapan, 6,000 feet.

ANNONACEAE

Annona Cherimola Mill. *Chirimoya*. No. 1228, *malpais* south of Uruapan, 6,000 feet; common in pastures of vicinity.

Annona reticulata L. No. 1312, tree thirty feet high, mesic forest, damp soil, La Majada, 1,200 feet; bark tough, fibrous, used as substitute for rope.

Annona longiflora Wats. No. 1638, tree fifteen feet high, open pine forest above Acahuato, 3,200 feet; also known as *Chirimoya*.

LAURACEAE

Persea americana Mill. No. 1632a, tree twenty-five feet high, cultivated, Acahuato, 3,000 feet.

Phoebe effusa Meissn. No. 1071, tree twenty feet high, growing in barranca, Cerro San Miguel; fairly common.

HERNANDIACEAE

Gyrocarpus americanus Jacq. No. 1427, tree twenty-five feet high, mesic woods near Hacienda California, 1,200 feet; common species of mesic forests in parts of valley, reaching a height of fifty feet.

PAPAVERACEAE

Argemone platyceras Link & Otto. No. 705, flowers white, common to abundant in fields at 6,000 to 7,000 feet.

Bocconia arborea Wats. No. 1227, tree up to thirty feet high, usually lower, *malpais* south of Uruapan, 6,000 feet.

CAPPARIDACEAE

Capparis angustifolia HBK. *Oliva*. No. 426, tree fifteen feet high, fruits when split open bright orange and very conspicuous; common on flat plains near Río Tepalcatepec, 1,000 feet.

Capparis flexuosa L. No. 1322, tree fifteen feet high, mesic forest, La Majada, 1,200 feet.

Forchhammeria pallida Liebm. No. 1471, tree fifty feet high, dark, smooth bark, arid-mesic transition, near stream, west of Apatzingan, 1,200 feet; not common.

Polanisia viscosa (L.) DC. No. 1424, common on dry waste land around Apatzingan, 1,200 feet.

CRUCIFERAE

Draba Pringlei Rose. Nos. 276, 1138; Cerro Tancítaro, rocky ledges, 10,000 feet to peak, more abundant at higher altitudes.

Eruca sativa Mill. No. 578, waste field near the Pedregal, common, 6,000 feet.

Lepidium virginicum L. No. 581, waste field near the Pedregal, 6,000 feet.

Romanschulzia arabiformis (DC.) Rollins. Nos. 1207, 4034; cloud forest, plant up to five feet high, flowers white; rare from 8,200 to 9,000 feet, abundant in open, very steep slopes and cliffs from 9,000 to 9,500 feet.

SAXIFRAGACEAE

Heuchera mexicana Schaffn. No. 290, moist cliffs above 9,500 feet; rather rare.

ROSACEAE

Alchemilla procumbens Rose. Nos. 283, 1085, 1088, 1144; Cerro Tancítaro; very common in open pine forest above 9,500 feet, especially on ridges, more abundant at higher altitudes.

Alchemilla sibbaldiaefolia HBK. No. 1178, common on moist slopes, north side of Cerro Tancítaro, 10,800 feet.

Alchemilla subalpestris Rose. No. 1219, growing submerged in pools of marshy meadow, north side of Cerro Tancítaro, 10,500 feet.

Crataegus pubescens (HBK.) Steud. *Tejocote*. Nos. 556, 573; near the Pedregal, 6,000 feet; common tree on plateau from 5,000 to 7,000 feet, reaches height of thirty feet.

Holodiscus fissus (Lindl.) Schneid. No. 676a, shrub, rocky ridge, Cerro Tancítaro, 10,000 feet.

Licania arborea Seem. Nos. 452, 1448, tree up to fifty or sixty feet, common in mesic forests of river valley, 1,200 feet.

Photinia mexicana (Baill.) Hemsl. Nos. 1024, 1041, shrub or small tree up to fifteen feet high, fruits red and edible; common among rocks in the Pedregal, 6,000 feet.

Prunus Capuli Cav. *Capulin*. No. 366, tree up to sixty feet high; common along barrancas from 5,000 to 7,200 feet.

Rubus adenotrichus Schlecht. No. 532, shrub up to twelve feet high; common on plateau from 5,000 to 7,000 feet.

KRAMERIACEAE

Krameria secundiflora DC. No. 1832a, vine, arid plains near the foot of Cerro Apatzingan, apparently rare.

LEGUMINOSAE

Acacia angustissima (Mill.) Kuntze. Nos. 1401, 1749, 1800, tree twenty feet high, arid scrub forest west of Apatzingan, 1,200 feet.

Acacia cymbispina Sprague & Riley. *Huisache*. No. 477, tree ten to twenty feet high, flowers yellow; one of the commonest trees in the arid scrub forest, 1,200 feet.

Acacia macrantha H. & B. No. 441, tree twenty to thirty feet high, arid plains near El Capiri, Río Tepalcatepec, 1,000 feet.

Acacia pennatula (S. & C.) Benth. Nos. 1628, 1775; scrubby tree ten to fifteen feet high, with wide spreading crown; common in open pine forest from 3,000 to 4,000 feet.

Acacia riparia Benth. Nos. 408, 421, 421a; tree fifteen to thirty feet high, flowers white; common throughout arid scrub forests, especially near streams.

Apoplanesia paniculata Presl. Nos. 1463, 1503, 1755; tree fifteen to twenty feet high; common throughout arid parts of tropical zone from 1,000 to 3,000 feet.

Bauhinia longiflora Cav. No. 1347a, tree twelve to fifteen feet high, often low, spreading and shrublike, mesic forest, La Majada, 1,200 feet.

Brogniartia podalyrioides HBK. No. 502, shrub up to five feet high, flowers purple, found between 2,800 and 3,500 feet; not common.

Caesalpinia platyloba Wats. Nos. 424, 1380, 1466; tree five to twenty feet high; very common in arid scrub forest throughout valley, 1,000 to 1,200 feet.

Caesalpinia pulcherrima (L.) Sw. Nos. 403, 1365, 1377; shrub six to twelve feet high, showy orange flowers; common in arid parts of tropical zone, 1,000 to 3,000 feet.

Calliandra callistemon (Schlecht.) Benth. Nos. 1418, 1625, 1639, low shrub, usually one to two feet high, flowers scarlet; common in open pine forest from 3,000 to 4,000 feet.

Calliandra densifolia Rose. Nos. 1362, 1412, tree ten to twelve feet high; common in thick scrub forest of arid plains.

Calliandra Houstoniana (Mill.) Standl. No. 389, open pine forest, trail from Tancítaro to Apatzingan; very common about 4,000 to 5,000 feet.

Calliandra strigillosa (Britt. & Rose) Standl., comb. nov. *Anneslia strigillosa* Britt. & Rose, N. Amer. Fl. **23**:71. 1928. No. 999, shrub up to five feet high; common in pine forest four miles west of Uruapan, 6,000 feet.

Cassia laevigata Willd. No. 586, shrub ten to fifteen feet high, field near Tancítaro, 6,000 feet.

Cassia rotundifolia Pers. No. 1306, rocky pasture, two miles west of Uruapan, 6,000 feet.

Cassia Skinneri Benth. No. 1661, tree twelve feet high, arid slopes above 2,000 feet; very localized.

Cassia Tora L. No. 448, flowers yellow, up to two feet high, fields near Apatzingan, 1,200 feet.

Cassia uniflora Mill. No. 493, open pasture one mile south of Apatzingan, common.

Cologania erecta Rose. No. 385, common in open pine woods from about 4,000 to 5,000 feet.

Cologania racemosa Rose. No. 602, common in rich soil along stream near the Pedregal, 6,000 feet.

Crotalaria angulata Mill. No. 4006, field near the Pedregal, 6,000 feet.

Crotalaria longirostrata H. & A. Nos. 266, 291, up to three feet high, abundant locally in open fields from 5,000 to 7,000 feet.

Crotalaria sagittalis L. Nos. 297, 518; common in fallow fields from 5,000 to 7,000 feet.

Crotalaria vitellina Ker. No. 616, open pine forest, 5,000 feet; No. 1450, roadside near Hacienda California, edge of mesic woods, 1,200 feet; common.

Desmodium plicatum C. & S. No. 1291, shrub four feet high, open, rocky pasture west of Uruapan, 6,000 feet; No. 1651, open pine forest above Acahuato, 3,200 feet; shrub about four feet high, common.

Desmodium strobilaceum Schlecht. No. 615, twining vine, flowers pink, open pine forest along trail from Tancítaro to Apatzingan, 5,000 feet; No. 1421, damp ravine, pine forest, La Cañada, 4,000 feet.

Diphysa floribunda Peyr. Nos. 1512, 1705; steep arid slopes of canyons below Acahuato, 2,000 to 2,500 feet; fairly common on arid slopes up to 3,000 feet.

Enterolobium cyclocarpum (Jacq.) Griseb. No. 1457, tree eighty feet high, with large, spreading crown, open field near stream, Hacienda California; common near streams up to 4,000 feet. Grows, when planted, up to 6,000 feet.

Eriosema pulchellum (HBK.) Don. No. 1819, flowers yellow, common in open pine forest, 3,000 to 4,000 feet.

Erythrina americana Mill. *Colorín.* No. 1399, tree eight feet high, arid scrub forest near La Majada, 1,200 feet; common in arid parts of the *tierra caliente* up to 3,000 feet, reaches height of eight to ten feet. Seeds formerly used by Indians as source of poison for arrows.

Haematoxylon Brasiletto Karst. No. 1498, shrub or small tree, arid slopes of Cerro Apatzingan, 2,000 feet.

Indigofera Palmeri Wats. No. 1730, shrub six to eight feet high, steep, arid slopes above canyon, 2,000 feet.

Inga spuria H. & B. No. 445, tree forty feet high, mesic forest along Río San Antonio near El Capiri, 1,000 feet.

Lonchocarpus sp. No. 1549, tree forty feet high, arid slopes below Acahuato, 2,500 feet.

Lupinus elegans HBK. No. 668, plant ten feet high, flowers purple, spruce forest at about 9,000 feet, fairly common in more open parts; No. 1080, tree twelve feet high, flowers white, open pine forest, Cerro San Miguel, 6,700 feet, not common; No. 4035, five to seven feet high, mountain meadow, 9,500 feet, Cerro Tancítaro.

Lupinus Aschenbornii Schauer. No. 1157, flowers light blue, open pine forest near summit, mostly on north slope, Cerro Tancítaro, 11,000 feet.

Lupinus geophilus Rose. No. 274, flowers blue, near summit of Cerro Tancítaro, above 11,000 feet.

Lupinus montanus HBK. No. 1128, open pine forest, Cerro Tancítaro, very common from 9,500 feet to the summit.

Lupinus persistens Rose. Nos. 282, 1136, 1177; Cerro Tancítaro, common in open pine forest to summit; up to four feet high, forming solid stands in places, above 3,500 feet.

Lysiloma microphylla Benth. Nos. 1390, 1391, 1500, 1543, 1750; tree ten to twenty feet high, flowers white; very common throughout arid parts of the *tierra caliente* up to 2,000 feet.

Mimosa albida Humb. & Bonpl. No. 1007, dry, rocky places, common just west of Uruapan, 6,000 feet.

Mimosa distachya Cav. No. 459, shrub four to eight feet high, flowers pale lavender, common on arid plains, 1,000 to 1,200 feet.

Mimosa Galeottii Benth. No. 365, tree ten feet high, flowers white, field one mile south of Tancítaro, 6,000 feet; rare.

Mimosa spirocarpa Rose. No. 1752, shrub twelve feet high, growing beside irrigation ditches near Apatzingan, 1,200 feet.

Mimosa Xanti Gray. No. 1478, shrub six feet high, arid slopes, 2,500 feet.

Phaseolus heterophyllus H. & B. No. 373, fallow fields around Tancítaro, 6,000 feet; common.

Phaseolus acutifolius Gray. No. 614, climbing vine, flowers pink, open pine forest, 5,000 feet.

Phaseolus formosus HBK. No. 550, climbing over shrubs, rich soil, edge of stream near the Pedregal, 6,000 feet.

Phaseolus sp. No. 1530, vine climbing over low shrubs in partial shade, arid canyon below Acahuato, 2,500 feet.

Piptadenia platycarpa (Rose) Macbr. No. 1351, tree fifteen feet high, mesic woods.

Piscidia piscipula (L.) Sarg. No. 1491, tree twenty feet high, open arid slopes below Acahuato, fairly common, 1,200 to 3,000 feet.

Pithecolobium dulce (Roxb.) Benth. No. 1455, mesic woods west of La Majada, 1,200 feet; No. 1824, stream valley above Acahuato, 3,200 feet, common; tree up to thirty-five or forty feet high, spreading.

Pithecolobium lanceolatum (HBK.) Benth. No. 1320, 1345, La Majada, near streams; No. 1440, near swamp, Hacienda California; tree twenty to thirty feet high, common in mesic forests of valley.

Pithecolobium velutinum B. & R. No. 1739, tree twenty-five to thirty feet high, arid plains, trail from Apatzingan to El Capiri, 1,000 feet; common.

Prosopis juliflora (Sw.) DC. No. 1428, spreading tree thirty feet high, near Hacienda California; common throughout arid plains from 1,000 to 1,200 feet, usually in low areas.

Rhynchosia nigropunctata Wats. No. 1652, common vine in open pine forest, 3,000 to 5,000 feet.

Tamarindus indicus L. No. 1456, tree eighty feet high, open field near stream; common tree in mesic situations from 1,000 to 1,200 feet.

Tephrosia cuernavacana (Rose) Macbr. Nos. 628, 1789; shrub up to three feet high, rocky cliffs at Las Barranquillas, 4,000 feet.

Tephrosia toxicaria (Sw.) Pers. No. 1624, herb up to four feet high, open pine forest, 3,200 feet.

Trifolium amabile HBK. No. 529, flowers white, common in open pine woods, north of Tancítaro village at 6,500 feet.

Trifolium mexicanum Hemsl. No. 564, open woods near the Pedregal, 6,000 feet; fairly common.

Zornia diphylla (L.) Pers. No. 1820, flowers yellow, common in open pine forest from 3,000 to 4,000 feet.

OXALIDACEAE

Oxalis albicans HBK. Nos. 1051, 1052; vine growing four to six feet long, twining over bushes in fields and barrancas four miles east of Tancítaro, 6,000 feet.

Oxalis alpina Rose. Nos. 315, 4025; very common, growing among rocks, on cliffs and ridges near summit in sun or shade, Cerro Tancítaro, 9,500 feet to summit.

Oxalis lanceolata (Small) Knuth. No. 267, common, growing in detritus of pine needles, pine woods from 5,000 to 7,200 feet.

GERANIACEAE

Geranium aristisepalum H. E. Moore. Nos. 393, 609; common in open pine forests from 5,000 to 6,000 feet on the southern part of the plateau.

Geranium Seemanii Peyr. No. 693, rocky ridges above 9,500 feet, Cerro Tancítaro, fairly common.

LINACEAE

Linum mexicanum HBK. No. 635, trail from Tancítaro to Apatzingan, open pine forest, about 5,000 feet.

ERYTHROXYLACEAE

Erythroxylon Pringlei Rose. Nos. 1378, 1499; small tree or shrub fifteen to twenty feet high, plains and lower arid slopes, fairly common, 1,000 to 2,500 feet.

Erythroxylon mexicanum HBK. No. 1592, tree fifteen feet high, growing in shade beside stream, canyon below Acahuato, 2,000 feet.

ZYGOPHYLLACEAE

Guaiacum Coulteri Gray. *Guayacán.* Tree twenty to thirty-five feet high, common throughout arid plains.

Kallstroemia Rosei Rydb. No. 439, spreading herb, moist soil near pond, El Capiri, 1,000 feet.

Kallstroemia glabrata Rydb. Nos. 492, 495; spreading herb, flowers yellow, common in open pastures and waste land about Apatzingan, 1,200 feet.

Kallstroemia maxima (L.) T. & G. *Hierba de paloma.* Nos. 1414, 1423; spreading herb common in open pastures and waste land around Apatzingan.

Kallstroemia brachystylis Vail. No. 1489, arid lower slopes of Cerro Apatzingan, 1,400 feet, not common.

Tribulus cistoides L. Nos. 474, 497, common weed in waste fields and pastures around Apatzingan, sometimes so abundant as to give a yellow appearance to entire pastures.

SIMARUBACEAE

Recchia mexicana M. & S. No. 453, small tree, bank of Río Apatzingan, in open situation, 1,200 feet.

BURSERACEAE

Bursera bicolor (Willd.) Engler. *Copal.* Nos. 1531, 1694, tree fifteen to thirty feet high, common on steep, arid slopes up to 3,000 feet, also found on plains.

Bursera bipinnata (S. & M.) Engler. *Copal.* Nos. 1241, 1290, tree eight to ten feet high, common on rocky land around Uruapan, 6,000 feet.

Bursera confusa (Rose) Bullock. No. 1277, tree ten feet high, smooth, reddish bark, brilliant orange-red when cut, rocky pasture west of Uruapan, 6,000 feet; No. 1515, tree twelve feet high, steep side of canyon below Acahuato, 2,500 feet.

Bursera fagaroides (HBK.) Engler. Nos. 1518, 1547, 1708, 1765a; tree ten to twenty feet high, bark smooth, pale green, peeling papery and reddish, aromatic but disagreeable odor, very common on arid slopes between 1,200 and 3,000 feet.

Bursera glabrifolia (HBK.) Engler. Nos. 1690, 1695, tree fifteen to twenty feet high, open pine forest above Acahuato, 3,200 feet.

Bursera grandifolia (Schlecht.) Engler. Nos. 1396, 1523, 1546, 1740, 1764; tree fifteen to thirty feet high, smooth, dark gray bark, common throughout arid parts of tropical zone, 1,000 to 3,000 feet.

Bursera jorullensis (HBK.) Engler. Nos. 1273, 1464, 1514, 1711, 1760; tree ten to twenty feet high, common throughout lower arid tropical zone, especially on slopes between 1,200 and 2,000 feet.

Bursera sessiliflora Engler. No. 1825, tree fifteen feet high, open pine forest, Las Barranquillas, 4,000 feet; common between 3,000 and 4,000 feet.

Bursera Simaruba (L.) Sarg. *Papelillo*. No. 1461, tree fifty feet high, beside stream, thick mesic forest, eight miles west of Apatzingan, 1,200 feet.

Bursera subtrifoliolata (Rose) Standl. No. 1596, tree ten feet high, smooth, reddish bark, steep, arid side of canyon, 2,500 feet.

Bursera Tecomaca (DC.) Standl. No. 1526, tree fifteen feet high, smooth, reddish bark, arid side of canyon, 2,500 feet.

Bursera trifoliolata Bullock. Nos. 1385, 1468, 1742; tree twenty to forty feet high, bark smooth, dark green, peeling in papery, reddish scales, arid plains, 1,000 to 1,200 feet; not common.

Bursera trimera Bullock. No. 1761, tree up to fifteen feet high, very common on top of arid hill east of Apatzingan, 1,500 feet.

MELIACEAE

Trichilia hirta L. Nos. 471, 1313, 1387; shrub or tree eight to sixty feet high, larger trees with crown of branches at top, bark smooth, red, borders of streams and mesic woods throughout river valley.

MALPIGHIACEAE

Bunchosia biocellata Schlecht. No. 1358, tree ten feet high, mesic forest near La Majada, 1,200 feet.

Byrsonima crassifolia (L.) DC. *Changunga* or *Nanche*. Nos. 1609, 1648, 1737, 1832; small tree up to twenty feet high, very common on arid slopes between 2,500 and 3,000 feet, extending up into pine forests to 3,500 feet.

Heteropteris laurifolia (L.) Juss. Nos. 1602, 1723; shrub five to ten feet high, often spreading, flowers yellow, canyons below Acahuato, near water, 2,500 feet.

Heteropteris Palmeri Rose. No. 1535, shrub eight to ten feet high, canyon below Acahuato, 2,000 feet.

Malpighia Galeottiana Juss. *Maca*. Nos. 429, 439a; tree twenty to thirty feet high, arid plains near El Capiri on the Río Tepalcatepec, 1,000 feet.

Malpighia mexicana Juss. Nos. 1375, 1724, 1754; tree ten to fifteen feet high, fairly common in arid scrub forest and on arid slopes up to 2,500 feet.

POLYGALACEAE

Polygala glochidiata HBK. No. 1281, open meadows west of Uruapan, 6,000 feet, common.

Polygala longipes Blake. No. 643, suffrutescent, open pine forest between Tancítaro and Apatzingan, 1,400 feet; No. 1501, arid slopes on Cerro Apatzingan, 1,400 feet.

Polygala rivinifolia HBK. No. 1803, open pine forest, 3,000 to 4,000 feet.

Polygala subalata Wats. No. 300, common in open meadows and fallow fields around Tancítaro, 6,000 feet.

Monnina Schlechtendaliana Dietr. No. 712, shrub, flowers blue, beside stream in open, 7,000 feet.

Monnina xalapensis HBK. No. 4014, shrub six feet high, beside stream, 7,000 feet.

EUPHORBIACEAE

Acalypha grisea Pax & Hoffm. No. 1718, shrub, arid sides of canyon, 2,000 feet.

Acalypha setosa A. Rich. No. 1363, arid scrub forest, four miles west of Apatzingan, common in partial shade or full sun, 1,200 feet.

Acalypha subviscida Wats. Nos. 399, 1645, 1780; shrub up to four feet high, very common in open pine forest from 3,000 to 5,000 feet or higher.

Acalypha vagans Cav. var. *genuina* M. Arg. No. 605, shrub about four feet high, trail from Tancítaro to Apatzingan, open pine forest, 5,000 feet.

Croton calvescens Wats. No. 603, shrub up to four feet high, pasture near the Pedregal, common, 6,000 feet.

Croton flavescens Greenm. No. 1545, shrub three to four feet high, steep, arid slopes, 1,400 feet; No. 1550, shrub, arid slopes, 1,400 feet; No. 1725, shrub eight feet high, open pine forest, 3,200 feet.

Croton lobatus L. No. 494, open fields one mile south of Apatzingan, 1,200 feet; common on dry plains throughout the *tierra caliente*.

Croton niveus Jacq. No. 1409, tree ten feet high, scrub forest near La Majada; fairly common tree in arid scrub.

Euphorbia campestris C. & S. No. 248, field north of Tancítaro, 6,500 feet.

Euphorbia graminea Jacq. No. 608, open pine forest, about 5,000 feet; common between 4,000 and 5,000 feet.

Euphorbia hirta L. No. 1342, mesic forest at La Majada, 1,200 feet; No. 1655, open pine forest, 3,200 feet, common.

Euphorbia hyssopifolia L. Nos. 1506, 1509; arid slopes in arroyo, Cerro Apatzingan, 1,300 feet.

Euphorbia potosina Fern. No. 512, arid slopes at base of Cerro Apatzingan, 1,300 feet; very common.

Euphorbia Schlechtendalii Boiss. Nos. 1529, 1544; shrub eight to twelve feet high, arid slopes and canyons, about 1,500 feet.

Euphorbia umbellulata Engelm. Nos. 511, 1486, arid slopes, Cerro Apatzingan, 1,300 feet; common.

Jatropha angustidens (Torr.) Muell. Arg. *Malo hombre, Ortiga*. No. 461, near Río Apatzingan, south of the town; common throughout the valley.

Jatropha tubulosa Muell. Arg. *Malo hombre*. No. 1416, arid plains near La Majada; one of the commonest plants in arid scrub zone.

Manihot aesculifolia (HBK.) Pohl. No. 1444, mesic to arid forest near swamp, Hacienda California, 1,200 feet.

Manihot angustiloba (Torr.) Muell. Arg. No. 1548, shrub five feet high, edge of barranca, arid slopes, 1,400 feet.

Manihot caudata Greenm. No. 541, vine climbing on small trees, bank of Río Apatzingan, south of town of Apatzingan.

Manihot mobilis Standl., sp. nov.

Frutex 2.5 m. altus, interdum subscandens, omnino glaber, ramulis crassiusculis, vetustioribus brunneis; folia inter minora, longipetiolata, petiolis gracilibus inaequalibus 2-8 cm. longis; lamina 5-10 cm. longa et aequilata, fere ad basin 5-3-loba, membranacea, glabra, subtus paullo pallidior, lobo terminali late obovato vel elliptico-obovato 2-4 cm. lato, apice acuta usque rotundata, saepe subacuminata vel acute acuminato-apiculata; integro, lobis lateralibus conformibus sed brevioribus, lobis infimis parvis vel rarius subnullis, 1-2 cm. tantum longis, reflexis, oblongis vel lineari-oblongis, apice acutis usque rotundatis; stipulae minimae vel nullae; inflorescentiae terminales vel laterales laxe pauciflorae 5 cm. longae vel breviores, pedicellis floriferis 5-8 mm. longis, crassiusculis, adscendentibus, fructiferis usque ad 4 cm. longis; perianthium masculum campanulatum ca. 1 cm. longum et fere aequilatum, extus intusque glabrum, lobis brevibus late ovatis; floris feminei discus crassus 3 mm. latus; ovarium globoso-ovale obscure costatum; capsula (imperfecta) ovali-globosa ca. 17 mm. alta.

MEXICO: Michoacán: Thorn forest between Apatzingan and La Majaca, alt. 1,200 ft., a climbing vine, August 13, 1941, William C. Leavenworth and H. Hoogstraal 1556 (type in Herb. Chicago Nat. Hist. Mus.). Canyon below Acahuato, shrub 8 ft. high, on arid hillside with scrub forest, 2,500 ft., August 14, 1941, Leavenworth & Hoogstraal 1532.

This clearly is not referable to any of the species of *Manihot* cited from Mexico and Central America in the recent account of the genus by Croizat (Journ. Arnold

Arb. **23**:216. 1942). It is noteworthy for the small leaves with entire divisions. Possibly it is only a form of *M. mexicana* I. M. Johnston, but material referred to that species by Croizat exhibits such great variation that it seems probable that the specimens will have to be realigned when ampler material has been assembled.

Manihot tomatophylla Standl., sp. nov.

Arbor 9-metralis, omnino glabra, ramulis crassis, vetustioribus fusco-brunneis; folia majuscula, petiolo gracili 7-17 cm. longo; lamina membranacea, 8-12 cm. longa et aequilata, profunde fere ad basin 5-loba, lobis panduriformibus, 3.5-4.5 cm. latis, apice dilatatis et truncatis, breviter mucronatis, paullo supra mediam profunde constrictis, integris, prope basin valde angustatis; pedicelli fructiferi usque at 4 cm. longi; capsula subglobosa ca. 2 cm. alta et aequilata, apice late rotundata, manifeste angulata.

MEXICO; Michoacán: Bank of small dry arroyo near La Majada, a tree 30 ft. high with milky sap, common, alt. 1,200 ft., August 9, 1941, William C. Leavenworth & H. Hoogstraal 1402 (type in Herb. Chicago Nat. Hist. Mus.).

For separation of the Mexican species of this group more stress seems to have been placed on leaf form than any other character. By its leaves the present species is easily recognized, for they are manifestly unlike those of any other species of North America, their lobes conspicuously panduriform but otherwise entire, and all of them truncate or nearly so at the apex.

Phyllanthus micrandrus Muell. Arg. No. 1413, shrub seven feet high, in shade in thick woods, arid scrub forest near La Majada.

Phyllanthus perpusillus Standl., sp. nov.

Herba pusilla annua erecta usque ad 6.5 cm. alta, inferne simplex, superne ramulos 2-4 emittens, omnino glabra, caule ca. 0.4 mm. crasso, ramulis teretibus vel subteretibus, 1.5-3.5 cm. longis, laxis, patentibus vel adscendentibus, internodiis inferioribus elongatis, superioribus brevibus; stipulae scariosae, subulatae vel lanceolatae, petiolis subaequales; folia breviter petiolata tenuiter membranacea, petiolo usque 1 mm. longo; lamina elliptica usque ovali-elliptica vel saepe obovato-elliptica, 5-8 mm. longa, 2.5-5 mm. lata, apice rotundata, basi rotundata usque cuneato-acuta, subtus paullo pallidior, penninervia, nervis lateralibus utroque latere ca. 3, obscuris vel saepe obsoletis; flores monoeci, masculis ex axillis superioribus ortis, brevissime pedicellatis, singulis vel 2-3-fasciculatis, sepalis 4 ca. 1 mm. longis albidis; stamina 2, filamentis tota longitudine in columnam connatis; antherae didymo-globosae, transverse birimosae; flores feminei in axillis solitarii, pedicellis crassiusculis petiolis paullo longioribus, sepalis 6, obovatis, apice rotundatis et apiculatis, scariosis, 1-costatis, ad costam viridescentibus, paullo ultra 1 mm. longis; capsula depresso-globosa, 2 mm. lata vel paullo ultra, apice subtruncata, laevis; semina laevia fusco-brunnescentia.

MEXICO: Michoacán: Rocky pasture 2 miles west of Uruapan, common, tiny when mature, alt. 6,000 ft., August 2, 1941, William C. Leavenworth & H. Hoogstraal 1282 (type in Herb. Chicago Nat. Hist. Mus.).

If the several plants collected are normal, they average much smaller than in any other Mexican species of *Phyllanthus*. The general appearance is that of small individuals of *P. lathyroides* HBK., but that has different flower details, and also has leaves that are normally larger, variously oblong, and with a conspicuous lateral venation of more numerous nerves.

Stillingia zelayensis (HBK.) Muell. Arg. No. 1821, shrub three to four feet high; common in open pine forest from 3,300 to 4,000 feet and probably higher.

ANACARDIACEAE

Cyrtocarpa procera HBK. *Antiquipus*. Nos. 1372, 1465, 1747, 1758; tree thirty to forty feet high, spreading crown, bark gray, smooth or warty with age; common on arid plains and slopes up to 3,000 feet.

Mangifera indica L. No. 1613, tree thirty-five feet high, near stream in bottom of arid canyon, 2,500 feet; No. 1632, tree forty feet high, cultivated, Acahuato, 3,000 feet.

Comocladia mollissima HBK. No. 1551, shrub or small tree up to seven or eight feet high, arid slopes between 1,200 and 3,000 feet, very poisonous to the touch.

Pseudosmodingium perniciosum (HBK.) Engl. Nos. 1706, 1710, 1757; tree reaching a height of thirty feet, smooth, red, papery bark, wide-spreading habit; very common throughout the arid tropical zone, poisonous to the touch.

Rhus terebinthifolia Schlecht. & Cham. Nos. 1699, 1798; shrub four feet high, open pine forest from 3,200 to 4,000 feet.

Rhus Toxicodendron L. No. 1817, growing on moist bank of barranca, Las Barranquillas, 4,000 feet, only specimen seen.

Spondias purpurea L. Nos. 1540, 1657, 1714, 1679; tree up to thirty feet high, smooth, gray bark, arid slopes and open pine forest from 1,200 to 3,500 feet.

CELASTRACEAE

Celastrus Pringlei Rose. No. 1023, shrub reaching height of five or six feet but spreading widely, ten feet or more; common among rocks at the Pedregal, 6,000 feet.

SAPINDACEAE

Cardiospermum Corindum L. No. 440, vine climbing on trees and shrubs, near El Capiri on Río Tepalcatepec, 1,000 feet.

Dodonaea viscosa (L.) Jacq. Nos. 1635, 1829; shrub four to ten feet high; very common in meadows of open pine forest at about 3,200 feet.

Serjania (sterile). No. 1388, arid scrub forest west of Apatzingan, 1,200 feet.

Thouinidium decandrum (HBK.) Radkl. No. 1376, tree eight feet high, arid scrub forest west of Apatzingan, 1,200 feet; No. 1597, tree fifteen feet high, cliffs along edge of arid canyon, 2,500 feet.

SABIACEAE

Meliosma dentata (Liebm.) Urb. No. 1089, tree forty to fifty feet high, growing in shaded barranca, Cerro San Miguel, 6,700 feet; No. 727, trees growing in solid stand along stream, damp canyon in cloud forest, 7,500 feet.

BALSAMINACEAE

Impatiens Balsamina L. No. 1634, common on moist rocks and stone walls, Acahuato, 3,000 feet.

RHAMNACEAE

Ceanothus coeruleus Lag. No. 522, shrub up to five feet high, open pine forest north of Tancítaro, 7,000 feet; found throughout the plateau above 5,000 feet, but not common.

Colubrina heteroneura (Griseb.) Standl. Nos. 437, 476, 1604, 1605, 1733; tree ten to twenty feet high, sometimes weak-stemmed and trailing over other trees; common throughout arid scrub forest and found less commonly on slopes up to 2,500 feet.

Colubrina macrocarpa (Cav.) Don. No. 1811, shrub four feet high, pine forest from 3,300 to 4,000 feet.

Rhamnus capreaeafolia Schlecht. No. 1031, tree fifteen feet high, the Pedregal, 6,000 feet.

Zizyphus sonorensis Wats. *Corungoro*. Nos. 428, 469, 1400, 1452, 1738; tree fifteen to fifty feet high, common throughout arid plains and extending into mesic forest in places.

VITACEAE

Cissus sicyoides L. No. 1538, vine, climbing over small trees in full sun, arid slopes, 1,500 feet.

Vitis tiliifolia Humb. & Bonpl. No. 1727, large vine, climbing over trees, arid slopes, 2,500 feet.

TILIACEAE

Heliocarpus occidentalis Rose. No. 1525, tree ten to fifteen feet high, arid canyon between Acahuato and Apatzingan, about 2,000 feet.

Muntingia Calabura L. No. 419, tree fifteen to twenty feet high, flowers white, near Rancho El Capiri on Río Tepalcatepec, arid scrub, 1,000 feet.

Tilia occidentalis Rose. Nos. 721, 4012; tree reaching height of fifty feet, along streams near the Pedregal, 6,000 feet; common along streams from 6,500 to 7,200 feet, where it is usually twenty to thirty-five feet high.

Triumfetta brevipes Wats. Nos. 618, 1771; shrub two to four feet high, flowers creamy yellow, open pine forest up to 5,000 feet.

MALVACEAE

Anoda cristata (L.) Schlecht. Nos. 487, 1368, 1346; common herb throughout the low tropical zone, both arid and mesic situations.

Kosteletzkya sagittata Presl. No. 1321, growing in mud near stream, mesic forest, La Majada, 1,200 feet.

Kosteletzkya hastata Presl. No. 1350, up to three feet high, stinging hairs, fairly common in mesic woods, La Majada, 1,200 feet.

Sida acuta Burm. No. 597, flowers yellow, shrubby plant growing in open fields near the Pedregal, 6,000 feet.

Sida angustifolia Lam. No. 1697, shrub three feet high, flowers creamy yellow, open pine forest, 3,200 feet.

STERCULIACEAE

Guazuma ulmifolia Lam. Nos. 1678, 1716; tree ten to twenty-five feet high, arid slopes below Acahuato, 1,200 to 3,000 feet; found throughout tropical zone.

Melochia pyramidata L. Nos. 496, 1425; common throughout arid tropical zone.

GUTTIFERAE

Calophyllum brasiliense var. *Rekoi* Standl. No. 1462, mesic forest, beside stream, Hacienda California, 1,200 feet.

Clusia Salvinii Donn. Smith. No. 1025, small tree up to fifteen feet high, common among rocks in the Pedregal, 6,000 feet.

Hypericum uliginosum HBK. No. 1063, common in fields around Tancítaro, 6,000 feet.

ELATINACEAE

Elatine triandra Schkuhr. No. 1220, growing submerged in a shallow pool in two to four inches of water, Cerro Tancítaro, 10,500 feet.

COCHLOSPERMACEAE

Amoreuxia palmatifida M. & S. No. 503, arid slopes at base of Cerro Apatzingan, 1,200 to 1,400 feet, abundant but apparently quickly transitory.

VIOLACEAE

Hybanthus attenuatus (Humb. & Bonpl.) Schulze. No. 1245, *malpais* south of Uruapan, 5,600 feet; No. 1359, arid scrub forest, among rocks, four miles west of Apatzingan, 1,200 feet.

Hybanthus riparius (HBK.) Standl. No. 402, rich, moist soil beside Río Apatzingan, two miles below the town, 1,200 feet.

Viola humilis HBK. Nos. 263, 4010; shaded slopes and ravines, open pine forest around Tancítaro, not abundant, 6,000 to 7,000 feet.

Viola Pringlei Rose & House. No. 697, pine woods, Cerro Tancítaro, 7,200 feet.

Viola prunellifolia HBK. No. 531, open pine woods around Tancítaro; fairly common, 6,000 to 7,000 feet.

FLACOURTIACEAE

Xylosma celastrinum (HBK.) Kuntze. Nos. 988, 1019; shrub six feet high, leaves glossy, common in damp woodlands adjoining the Pedregal, 6,000 feet.

TURNERACEAE

Turnera ulmifolia L. Nos. 624, 1250, 1627; common in open pine forest from 3,000 to 5,000 feet.

PASSIFLORACEAE

Passiflora mexicana Juss. Nos. 1507, 1516; vine, climbing on small trees and shrubs, arid slopes, 1,400 feet.

Passiflora viridiflora Cav. No. 1717, on rocky ledge in dense shade; not common, arid slopes, 1,600 feet.

CACTACEAE

Acanthocereus pentagonus (L.) Britt. & Rose. No. 1519d, on arid plains in scrub forest, about eight miles west of Apatzingan; common and abundant throughout many parts of the arid scrub forest.

Opuntia sp. No. 1519a, a large plant, up to 15 feet in height, very common and conspicuous on arid slopes from 1,200 to 1,400 feet.

Pachycereus pecten-aboriginum (Engelm.) Britt. & Rose. No. 1519b, large plant, up to thirty feet or more in height, common throughout most of the river valley, except in the tropical deciduous forest.

Selenicereus vagans (K. Brandeg.) Britt. & Rose. No. 1519c, clambering over rocks on the arid slopes and in canyons between 1,200 and 3,000 feet.

BEGONIACEAE

Begonia Balmisiana Ruiz. Nos. 254, 540; flowers pink or white, moist sides of barrancas, in heavy brown loam, near Tancítaro, 6,000 feet; common throughout plateau from 4,000 to 7,200 feet.

Begonia gracilis Kunth. No. 1274, rocky pasture west of Uruapan, 6,000 feet; No. 1770, open pine forest, 3,500 feet; common.

LYTHRACEAE

Cuphea appendiculata Benth. Nos. 606, 1785; herb or shrub, up to four feet high, usually eighteen to twenty-four inches, flowers purple; common in open pine forest from 4,000 to 5,000 feet.

Cuphea Bustamanta Llave & Lex. Nos. 4018, 4033; vinelike shrub, shady parts of ravine near stream, cloud forest, Cerro Tancítaro, 8,000 feet.

Cuphea Bustamanta var. *reipublicae* (Rob. & Seat.) Koehne. No. 335, trailing vine, dense shade, cloud forest, Cerro Tancítaro, 8,000 feet.

Cuphea imberbis Rose. No. 1268, *malpais* and rocky fields south of Uruapan, 6,000 feet; common.

Cuphea jorullensis HBK. No. 243, common in open pastures, 6,000 to 7,200 feet.

Cuphea laminuligera Koehne. No. 1578, arid slopes below Acahuato, 2,500 feet.

Cuphea lanceolata Ait. No. 293, creeping herb, flowers purple; common locally in pastures, 6,000 feet.

Cuphea lobophora Koehne. No. 513, slopes below Acahuato, 2,000 feet.

Cuphea micropetala HBK. var. *hirtella* Koehne. No. 1620, beside irrigation ditch, open field above Acahuato, 3,200 feet.

Cuphea Palmeri Wats. No. 1533, arid canyon between Acahuato and Apatzingan, 2,000 feet.

Cuphea ternata Peyr. No. 4003, grassy hillsides near the Pedregal, 6,000 feet.

Cuphea Watsoniana Koehne. No. 1251, dry slopes in open pine woods, near Cascada de Tzararacua, seven miles southwest of Uruapan.

Cuphea Wrightii Gray. No. 587, grassy meadow near the Pedregal, 6,000 feet; flowers purple, common; No. 1593, rocky ledges, arid canyon, 2,000 feet, rare; No. 1722, Cerro Apatzingan, flowers pink and white, 2,000 feet; No. 1792, open pine forest, Las Barranquillas, flowers purple, 4,000 feet.

Lythrum vulneraria Schrank. Nos. 258, 520, 642, shrub four to six feet high, very strict habit, shady situations in open pine forest, 5,000 to 7,000 feet.

MYRTACEAE

Eugenia cf. *origanoides* Berg. No. 1447, small tree, mesic-arid transition forest near Hacienda California.

Psidium Guajava L. *Guayaba*. No. 1294, tree twelve feet high, *malpais* south of Uruapan, 5,600 feet, common; No. 1637, tree ten to twelve feet high; fairly common along edge of pine forest above Acahuato, mostly in open fields, 3,200 feet.

ONAGRACEAE

Epilobium mexicanum DC. No. 1172, marshy meadow north side of Cerro Tancítaro, 10,500 feet; common very locally.

Fuchsia chiapensis Brandeg. No. 302, shrub two to ten feet high, the Pedregal, 6,000 feet; No. 641, shrub five feet high, near stream in open pine woods, 5,000 feet; common in zone of open pine woods from 5,000 to 7,000 feet or higher.

Fuchsia arborescens Sims. No. 1257, shrub seven feet high, flowers pink, wet cliffs at Tzararacua, 6,000 feet.

Fuchsia fulgens DC. Nos. 303, 1018; shrub, usually four to six feet high, very common in the Pedregal; also growing elsewhere on stone walls, trees, logs, etc., in damp situations from 6,000 to 7,500 feet.

Fuchsia microphylla HBK. Nos. 661, 4032, 1206; shrub three to ten feet high, becoming drooping and vinelike, flowers pink; common in upper cloud forest in dense shade from 8,000 to 9,500 feet; also found on steep cliffs among dense vegetation at 11,000 feet.

Fuchsia minimiflora Hemsl. No. 1059, compact shrub less than one foot high, flowers pink and white, edge of barranca four miles east of Tancítaro, 6,000 feet.

Fuchsia Pringlei Rob. & Seat. Nos. 356, 723; shrub four to eight feet high, flowers white, cloud forest along stream, 7,500 feet.

Gaura tripetala Cav. No. 294, waste field west of Tancítaro, along trail to Los Reyes, 6,000 feet.

Jussiaea suffruticosa L. No. 490, small shrub beside irrigation ditch, open field south of Apatzingan, 1,200 feet.

Jussiaea repens L. var. *peploides* (HBK.) Griseb. No. 491, moist soil beside irrigation ditch, open field, south of Apatzingan, 1,200 feet.

Lopezia pubescens HBK. No. 575, rich soil, the Pedregal, 6,000 feet; No. 676, very abundant on open, steep hillsides just above cloud forest limit, 9,500 feet, localized.

Lopezia racemosa Cav. Nos. 1114, 1186; suffrutescent shrub or herb, open, rocky ridges, Cerro Tancítaro, 9,500 feet.

Oenothera mexicana Spach. No. 4024, open meadows above 7,000 feet, Cerro Tancítaro.

Oenothera rosea Ait. No. 378, open pastures one mile south of Tancítaro, 6,000 feet.

Oenothera laciniata Hill. No. 244, fallow and waste fields and pastures, 6,000 to 8,000 feet; common.

ARALIACEAE

Aralia humilis Cav. No. 1684, shrub ten feet high, open pine forest, 3,200 feet; No. 1797, shrub four feet high, Las Barranquillas, 4,000 feet.

Gilibertia arborea (L.) March. No. 1072, tree thirty feet high, open pine forest on Cerro San Miguel, 6,700 feet.

Oreopanax Echinops (S. & C.) Planch. & Decaisne. No. 1107, tree ten to fifteen feet high, spreading, fairly common in barrancas, Cerro San Miguel, 6,700 feet.

UMBELLIFERAE

Apium leptophyllum (DC.) F. Muell. No. 359, cloud forest, shade, 8,000 feet.

Arracacia bracteata C. & R. No. 1199, four feet high; fairly common in cloud forest above 8,200 feet.

Arracacia vaginata C. & R. Nos. 268, 4011; growing in detritus of pine needles or on bare soil, open pine forest at 6,000 to 7,000 feet; common.

Coulterophytum Holwayi Rose. Nos. 566, 1032; small tree eight to twelve feet high, the Pedregal among rocks, 6,000 feet; common.

Deanea longibracteata C. & R. No. 1131, common on Cerro Tancítaro, above 9,500 feet, especially on rocky ridges.

Donnellsmithsia peucedanoides (HBK.) Math. & Const. No. 1772, herb three to five feet high, open pine forest, 3,400 feet.

Eryngium bromeliaefolium Delar. Nos. 673, 1163; very common throughout open pine forest and mountain meadows above 9,500 feet.

Eryngium Carlinae Delar. No. 4016, mountain meadow, 7,800 feet; not common.

Hydrocotyle umbellata L. No. 1442, in shallow water in swamp, Hacienda California, 1,200 feet.

Prionosciadium thapsoides (DC.) Mathias. No. 1495, seven feet high, lower slopes of Cerro Apatzingan, 1,400 feet.

Tauschia nudicaulis Schlecht. No. 284, in open pine parkland near summit, common.

Cornus disciflora DC. No. 1091, tree fifteen to twenty feet high, deep barranca, Cerro San Miguel, 6,700 feet; No. 1192, tree fifty feet high, forest along stream, Cerro Tancítaro, 8,200 feet; fairly common.

Cornus disciflora DC. var. *floccosa* (Wang.) Standl. No. 334, tree about forty feet high, forest near stream, Cerro Tancítaro, 8,000 feet.

CLETHRACEAE

Clethra lanata Mart. & Gal. No. 1049, shrub eight feet high, barranca four miles east of Tancítaro, 6,000 feet.

MONOTROPACEAE

Monotropa coccinea Zucc. No. 1184, dense cloud forest along stream, Cerro Tancítaro, 7,800 feet.

ERICACEAE

Arbutus spinulosa M. & G. No. 692, shrub one to two feet tall, open ridge, Cerro Tancítaro, 10,000 feet.

Arbutus xalapensis HBK. No. 569, tree twenty to twenty-five feet high, the Pedregal, 6,000 feet, common on plateau in rocky places; No. 1164, shrub two feet high, rocky ridge, Cerro Tancítaro, 10,500 feet.

Arctostaphylos angustifolia (Klotzsch) Hemsl. No. 1194, shrub four to six feet high, common on exposed ridges, 9,000 to 9,500 feet, Cerro Tancítaro.

Arctostaphylos rupestris Rob. & Seat. No. 585, tree ten feet tall, the Pedregal, 6,000 feet, not common; No. 667, shrub up to eight feet tall, exposed ridges, Cerro Tancítaro, 9,000 to 9,500 feet.

Pernettia ciliata (S. & C.) Small. Nos. 669, 1134; low shrub, sometimes up to two feet high, along streams and on exposed ridges, Cerro Tancítaro, above 9,500 feet.

THEOPHRASTACEAE

Jacquinia pungens Gray. *Pinicua.* No. 422, tree six to ten feet tall, arid plains near El Capiri, 1,000 feet; found throughout the arid scrub forest, common locally.

MYRSINACEAE

Ardisia revoluta HBK. No. 1599, shrub ten feet high, growing among rocks beside stream, in shade, arid canyon below Acahuato, 2,000 feet.

Parathesis serrulata (Sw.) Mez. No. 1068, barranca four miles east of Tancítaro, 6,000 feet.

Rapanea ferruginea (R. & P.) Mez. No. 1026, shrub six to eight feet high, the Pedregal, 6,000 feet.

PLUMBAGINACEAE

Plumbago pulchella Boiss. No. 1305, up to three feet high, rocky pastures west of Uruapan, 6,000 feet.

PRIMULACEAE

Anagallis arvensis L. No. 370, flowers salmon-colored, common in waste and fallow fields throughout the plateau, 6,000 feet and higher.

SAPOTACEAE

Bumelia persimilis Hemsl. Nos. 1558, 1393; tree fifteen to twenty feet high, arid scrub forest west of Apatzingan, 1,200 feet.

Calocarpum mammosum (L.) Pierre. No. 1459, tree forty feet high, mesic forest near stream, near Hacienda California, 1,200 feet.

Sideroxylon Capiri (A. DC.) Pittier. *Capiri*. Nos. 1382, 1432, 1454, 1474; tree up to sixty feet or more in height, common in mesic forest throughout tropical zone. In times of revolution the peasants are said to have lived almost entirely on the fruits of this tree.

EBENACEAE

Diospyros aequoris Standl. No. 1728, small tree, arid slopes, 2,400 feet; not common.

Diospyros Ebenaster Retz. *Zapote negro*. No. 1689, tree sixty feet high, Acahuato, 3,000 feet; No. 1433, tree sixty feet high, mesic forest near Hacienda California; common tree in mesic forest.

Diospyros Martineziana Standl., sp. nov.

Frutex vel arbor 2-4.5 m. alta, ut videtur dense ramosa, ramulis densissime piloso-tomentosis, internodiis brevibus vel brevissimis; folia parva, brevissime petiolata, chartacea et vulgo subrigida, petiolo vix ad 2 mm. longo pilosulo-tomentoso; lamina ambitu variabilis, orbicularis usque rotundo-ovalis vel interdum late obovato-elliptica, 1.5-4 cm. longa, 1.5-3 cm. lata, apice late rotundata usque obtusa, basi rotundata usque obtusa, utrinque dense molliter pilis ochraceis vel pallidioribus pilosa, nervis venisque subtus prominentibus, irregulariter reticulatis; flores trimeri, in axillis fasciculati vel cymosuli, brevissime pedicellati, pedicellis densissime hispidulis, crassiusculis; calyx profunde trilobus, extus dense pilosulo-tomentosus, intus dense sericeus, in alabastro 5 mm. longus, lobis late ovatis subacutis erectis.

MEXICO: Michoacán, Acahuato, open meadow above 2,500 ft., Municipalidad Apatzingan, a shrub with white flowers, August 20, 1941, William C. Leavenworth & H. Hoogstraal 1735 (type in Herb. Chicago Nat. Hist. Mus.). Dry arroyo, arid slope above Apatzingan, 2,000 ft., a shrub 7 ft. high, Leavenworth & Hoogstraal 1490. Above Apatzingan, arid slope with scattered trees, tree 15 ft. high, Leavenworth & Hoogstraal 1494. Above Apatzingan, arid slope with scattered trees, alt. 2,000 ft., 15 ft. high, Leavenworth & Hoogstraal 1502.

This plant is referable to the genus *Maba*, if that is separated from *Diospyros*, but at present most authors are in agreement in uniting *Maba* with *Diospyros*. Among the rather numerous Mexican species in the genus, the present one is rather well marked by its small and chiefly rounded or broadly oval leaves, very densely pubescent on both surfaces.

OLEACEAE

Fraxinus Uhdei (Wenzig) Lingelsheim. *Fresno*. No. 1042, tree up to sixty feet high, common along barrancas around Tancítaro, 6,000 feet.

LOGANIACEAE

Buddleia parviflora HBK. Nos. 691, 1204, 1118; shrub four to eight feet high, rocky ridges and steep slopes, 9,500 to 10,000 feet.

Spigelia scabrella Benth. *Maravilla*. No. 1261, fairly common on slopes in open pine-oak woods around the Cascada de Tzararacua, 6,000 feet.

GENTIANACEAE

Halenia plantaginea (HBK.) Griseb. Nos. 277, 1154, 1133; common on slopes of Cerro Tancítaro above 10,500 feet, mostly near summit and on north slope.

APOCYNACEAE

Haplophyton cimicidum A. DC. Nos. 1397, 450; small shrub up to two feet high, fairly common in scrub forest but usually in partial shade where conditions are somewhat mesic.

Plumeria rubra L. f. *acutifolia* (Poir.) Woodson. No. 1519, tree twenty-five feet high, flowers white with yellow center, milky sap, soft wood, large pith; fairly common on cliffs above and canyons from 1,200 to 2,500 feet.

Rauwolfia hirsuta Jacq. No. 1352, shrub four to five feet high, common on open, arid plains.

Rauwolfia hirsuta var. *glabra* (Muell. Arg.) Woodson. No. 475, shrub up to five feet high, flowers white, fruit red; common on open, arid plains, 1,200 feet.

Thevetia peruviana (L.) Pers. var. **pinifolia** Standl. & Steyerm., var. nov.

Frutex vel arbuscula 3-4.5 m. alta, formae typicae speciei similis; folia alterna vel prope apices ramulorum dense congesta, anguste linearia, subrigida, patentia vel adscendentia, plerumque 7-13 cm. longa, vix ultra 1 mm. lata, marginibus arcte revolutis, supra glabra nitida, subtus sparse denseve hirtella vel glabrata.

MEXICO: Michoacán: Trail from Apatzingan to Tancítaro, fairly common on the desert up to 2,500 ft., August 7, 1940, William C. Leavenworth 505 (type in Herb. Chicago Nat. Hist. Mus.). Above Apatzingan, common but localized as to altitudinal distribution, on arid slope with scattered trees, 2,000 ft., August 13, 1941, Leavenworth & Hoogstraal 1477. Bank of Río Apatzingan, 2 miles south of Apatzingan, fairly common on open plains, 1,200 ft., August 5, 1940, Leavenworth 463.

At first glance this plant seems to be wholly distinct from the common *Thevetia peruviana*, the very numerous, often crowded, long and spreading leaves being strongly suggestive of pine needles and of very different aspect from the relatively wide leaves of the usual form of *T. peruviana*. We should be inclined to treat the tree of the present collection as a distinct species, since it has foliage characters as good as those on which some other species of *Thevetia* are separated, but there are at hand two collections having leaves which, although much narrower than is normal in *T. peruviana* are nevertheless wider than in the type of var. *pinifolia*, attaining a width of 3 to 4 mm. These two collections, which may be referred to this variety, are the following: MEXICO: Guerrero: Vicinity of Acapulco, E. Palmer 27. Rocky headlands between Acapulco and Pie de la Cuesta, in 1935, L. H. MacDaniels 244.

Tabernaemontana amygdalifolia Jacq. No. 1340, tree fifteen feet high, mesic forest, La Majada, 1,200 feet.

Vallesia glabra Cav. Nos. 427, 1349; shrub twelve to fifteen feet high, sprawling over trees and shrubs; common in thick scrub forest where there is a transition to mesic conditions.

ASCLEPIADACEAE

Asclepias curassavica L. Nos. 486, 1347; common throughout arid plains and cultivated and waste fields of the *tierra caliente*.

Asclepias glaucescens HBK. No. 410, open field south of Apatzingan, 1,200 feet.

Asclepias neglecta Hemsl. Nos. 1633, 1783; fairly common in open pine forest from 3,000 to 4,000 feet.

Asclepias setosa Benth. No. 398, open pine forest, about 4,500 feet.

Asclepias ovata M. & G. No. 1105, open pasture at foot of Cerro San Miguel, 6,300 feet; fairly common.

Gonolobus jaliscensis Rob. & Greenm. No. 1244, vine, woody at base, *malpais* south of Uruapan, 5,600 feet.

Gonolobus congestus Dcne. No. 1683, twining on shrubs, open pine forest, 3,200 feet; fairly common.

Marsdenia propinqua Hemsl. No. 1431, vine climbing on small trees in thick thorn forest near Hacienda California; very common.

Mellichampia ligulata (Benth.) Vail. No. 1693, twining over shrubs, open pine forest, 3,200 feet.

CONVOLVULACEAE

Cuscuta applanata Engelm. No. 418, growing on herbs along stream, El Capiri, 1,000 feet.

Cuscuta corymbosa var. *grandiflora* Engelm. No. 702, growing on lupines, Cerro Tancítaro, 8,400 feet; common on a variety of hosts in cloud forest up to 8,500 feet.

Evolvulus alsinoides L. Nos. 1663, 1672; common in open pine forest, 3,000 to 4,000 feet.

Ipomoea arborescens (Humb. & Bonpl.) Don. No. 1765, tree thirty feet high, bark pale green and smooth, arid slopes below Acahuato, 2,800 feet.

Ipomoea longipedunculata Hemsl. No. 260, stone walls along fields south of Tancítaro, 6,000 feet; very common, covering stone walls from 5,000 to 7,000 feet.

Ipomoea mutabilis Lindl. No. 1075, climbing on small trees to height of thirty feet, flowers bright orange-red, Cerro San Miguel, 6,700 feet.

Ipomoea Seleri Millsp. No. 444, climbing over bushes and small trees, arid scrub near El Capiri, 1,000 feet.

Ipomoea suffulta Don. No. 1618, vine, prostrate or climbing over low shrubs, open pine forest, 3,200 feet.

Ipomoea tyrianthina Lindl. No. 1288, rocky pasture west of Uruapan, 6,000 feet.

Jacquemontia azurea (Desv.) Choisy. No. 1665, edge of cultivated field above Acahuato, 3,200 feet.

LENNOACEAE

Lennoa madreporioides L. & L. No. 1406, flowers lavender, common locally in arid locations from 1,000 to 3,000 feet.

HYDROPHYLLACEAE

Phacelia platycarpa (Cav.) Spreng. No. 265, very common herb in fields from 6,000 to 7,000 feet, forms almost continuous cover in isolated mountain meadows at 7,800 feet.

Wigandia caracasana HBK. No. 1668, shrub ten feet high, near stream, open pine forest, 3,200 feet; found up to altitudes of 5,000 feet or more.

BORAGINACEAE

Cordia dentata Poir. *Tamboro*. No. 1403, tree thirty feet high, very common in arid scrub forest, 1,200 feet.

Cordia brevispicata M. & G. No. 1243, *malpais* near Uruapan, 5,600 feet, common; No. 1681, shrub five to fifteen feet high; common in well-drained, rocky locations around Acahuato, 2,800 to 3,500 feet.

Cordia eleagnoides DC. *Cueramo*. Nos. 1379, 1561, 1753, 1759; tree fifteen to thirty feet high, very common throughout arid tropical zone, from Río Tepalcatepec to 3,000 feet.

Cynoglossum Pringlei Greenm. No. 552, damp soil in oak woods, the Pedregal, 6,000 feet.

Heliotropium fallax I. M. Johnston. No. 1505, arid slopes, Cerro Apatzingan, 1,400 feet.

Heliotropium fruticosum L. var. *erectum* (Macbr.) I. M. Johnston. No. 507, arid slopes, 1,300 to 2,000 feet; common.

Heliotropium indicum L. No. 498, up to two feet high, open pasture south of Apatzingan, 1,200 feet.

Heliotropium limbatum Benth. Nos. 400, 1687, common in open meadows in pine woods, 3,200 to 4,500 feet.

Heliotropium mexicanum Greenm. No. 1623, up to two feet high, common in open pine forest, 3,200 feet.

Heliotropium phyllostachyum Torr. No. 1367, arid scrub forest four miles west of Apatzingan, 1,200 feet; common.

Lithospermum discolor Mart. & Gal. No. 568, woods near the Pedregal, 6,000 feet.

Macromeria discolor Benth. Nos. 286, 4017; common in moist soil below cliffs, usually in shade, Cerro Tancítaro, 9,500 to 10,000 feet; also found in cloud forest down to 8,000 feet.

Macromeria exserta Don. No. 1773, open pine forest north of Acahuato, 3,400 feet.

Onosmodium strigosum Don. Nos. 317, 545, 599, 1774; open meadows in pine forest, 3,500 to 6,000 feet; common throughout its range, but not abundant.

Tournefortia densiflora M. & G. No. 252, shrub four to seven feet high, common along edges of fields and barrancas on plateau, 6,000 feet.

VERBENACEAE

Lantana Camara L. No. 1278, shrub four feet high, rocky pasture west of Uruapan, 6,000 feet.

Lippia nodiflora (L.) Michaux. Nos. 1356, 1441, 1325; growing in swampy fields or water throughout the river valley.

Priva lappulacea (L.) Pers. No. 1329, damp soil, La Majada, 1,200 feet.

Priva mexicana (L.) Pers. No. 1619, open pine forest, 3,200 feet.

Stachytarpheta jamaicensis (L.) Vahl. No. 479, moist soil near stream, south of Apatzingan, 1,200 feet.

Verbena carolina L. Nos. 269, 295; open fields, 6,000 to 7,000 feet; very common, especially in the streets of Tancítaro among the paving stones.

Verbena ciliata Benth. No. 292, prostrate, creeping plant; very common in fallow fields of plateau, 6,000 feet.

Verbena neomexicana (Gray) Small. No. 508, arid slopes, Cerro Apatzingan, 1,400 feet.

Vitex Hemsleyi Briq. No. 1707, tree fifteen feet high, arid slopes above canyon, 2,000 feet; common up to 3,000 feet.

Vitex mollis HBK. Nos. 1591, 1726, 1766; tree twenty-five to thirty-five feet high; common on arid slopes from 1,500 to 3,000 feet.

LABIATAE

Hyptis albida HBK. No. 1598, shrub ten feet high, spreading, beside stream in arid canyon, 2,000 feet.

Hyptis pectinata (L.) Poit. No. 1804, shrub four feet high, open pine forest, 3,500 feet; common.

Lepechinia spicata Willd. No. 588, the Pedregal, 6,000 feet; No. 617, along path in open field four miles south of Tancítaro, 6,000 feet.

Salvia cardinalis Epling. No. 1117, shrub four feet high, common just above the border of the cloud forest, on moist, open ridges, Cerro Tancítaro, 9,500 to 10,000 feet.

Salvia elegans Vahl. Nos. 354, 1115; shrub two to four feet high, common on ridges just above cloud forest, Cerro Tancítaro, 9,500 to 10,000 feet and higher.

Salvia gesneraeflora Lindl. & Paxt. Nos. 353, 660, 660a; shrub reaching a height of twelve or fifteen feet, cloud forest and open ridges above, Cerro Tancítaro, 8,500 to 10,000 feet; common.

Salvia glechomaefolia HBK. No. 607, along trail from Tancítaro to Apatzingan, open pine forest, about 5,000 feet.

Salvia Grahami Benth. No. 1001, shrub, flowers salmon-pink, open pine forest west of Uruapan, 6,000 feet.

Salvia longispicata M. & G. Nos. 349, 547; plant two to five feet high, common along the borders of fields and open woods, from 5,000 to 8,000 feet or higher.

Salvia mexicana L. No. 4045, plant two to three feet high, open parts of cloud forest, 7,500 to 9,000 feet.

Salvia aff. *nervata* Moq. No. 394, open pine forest near trail from Tancítaro to Apatzingan, 5,000 feet; common.

Salvia nigriflora Epling. No. 1269, common in pine forest west of Uruapan, 6,000 to 6,500 feet.

Salvia prunelloides HBK. No. 1000, along trail to Tancítaro, open pine forest west of Tancítaro, 6,000 feet.

Salvia Agnes Epling. No. 4036, blue flowers, tuberous root as large as medium-sized potato, cloud forest, Cerro Tancítaro, 9,000 feet.

Satureja laevigata Standl. No. 1183, shrub seven feet high, cloud forest in dense shade, Cerro Tancítaro, 9,100 feet; common.

Scutellaria caerulea M. & S. Nos. 311, 696, 1053; common in barrancas and damp, shady woods from 5,000 to 7,200 feet.

Stachys agraria C. & S. Nos. 372, 1067; very common in fields south of Tancítaro, 6,000 feet.

Stachys boraginoides C. & S. Nos. 313, 521; common in rich, damp soil in woods, 6,000 to 7,000 feet.

Stachys coccinea Jacq. No. 1324, moist soil, shade, beside stream, La Majada, 1,200 feet.

SOLANACEAE

Capsicum baccatum L. Nos. 458, 1339; shrub two to three feet high, mesic woods along stream, 1,200 feet.

Capsicum stramoniifolium (HBK.) Standl. No. 1259, shrub, fruit red, dense undergrowth, *malpais* south of Uruapan, 5,600 feet.

Cestrum Anagyris Dunal. No. 358, shrub ten to twelve feet high, dense undergrowth in cloud forest, 8,000 feet.

Cestrum thyrsoideum HBK. No. 538, shrub up to ten feet high, very common on plateau around Tancítaro, 6,000 feet.

Datura innoxia Mill. No. 409, pasture one mile south of Apatzingan, 1,200 feet.

Datura pruinosa Greenm. No. 1615, common in open parts of arid plains around Apatzingan, 1,200 feet.

Lycianthes Andrieuxii (Dunal) Bitter. No. 1008, open pine forest west of Uruapan, trail to Tancítaro, 6,000 feet.

Lycianthes lenta (Cav.) Bitter. No. 1315, vine, climbing over small trees up to fifteen or twenty feet, mesic forest, La Majada.

Lycianthes somniculenta (Kuntze) Bitter. Nos. 386, 526, pine forest from 4,500 to 7,200 feet; not abundant.

Nicotiana Tabacum L. No. 420, open field beside Río San Antonio, near El Capiri, 1,000 feet.

Physalis ixocarpa Brot. No. 1408, scrub forest four miles west of Apatzingan, 1,200 feet; No. 1769, rocky, well drained soil, open pine woods, 3,300 feet; No. 1787, moist soil beside stream, Las Barranquillas, 4,000 feet; not common.

Physalis pubescens L. No. 1381, arid scrub forest west of Apatzingan, 1,200 feet; not common.

Physalis subintegra Fern. Nos. 271, 1057; common in pastures and open pine forest to 7,000 feet; No. 1310, oak forest, road from Uruapan to Apatzingan, 4,000 feet.

Physalis viscosa L. No. 519, moist soil in pine woods, 6,500 feet; common locally.

Saracha procumbens (Cav.) R. & P. Nos. 598, 729; herb four to five feet high, common in woods near the Pedregal, 6,000 feet.

Solanum appendiculatum Dunal. No. 1084, moist soil in deep barranca, Cerro San Miguel, 6,700 feet.

Solanum brachystachys Dunal. Nos. 249, 355, 553; tree up to twelve feet high, flowers white; common on plateau, 6,000 to 7,000 feet.

Solanum Cervantesii Lag. Nos. 351, 698; shrub or small tree ten to fifteen feet high, common along barrancas on plateau and extending up to 8,000 feet in cloud forest on Cerro Tancítaro.

Solanum cornutum Lam. No. 1353, branching herb, shrublike in form, four to five feet high, mesic, open field near La Majada, 1,200 feet; Nos. 1415, 1384; low herbs, one to three feet high, arid scrub forest west of Apatzingan; common locally.

Solanum deflexum Greenm. No. 473, moist soil, sunny situation near El Capiri, 1,000 feet; No. 1279, open pasture, west of Uruapan, 6,000 feet; No. 1344, moist soil, sunny situation, La Majada, 1,200 feet.

Solanum demissum Lindl. No. 1212, flowers purple, common in rich soil in open and partial shade, 7,000 feet.

Solanum Galeotti Dunal. No. 312, vine climbing on small trees, the Pedregal, 6,000 feet.

Solanum hirtum Vahl. No. 1779, shrub four feet high, open pine forest, 4,000 feet; rare.

Solanum laurifolium Mill. No. 259, shrub four to seven feet high, flowers lavender, fruit yellow-orange; common in open fields of plateau up to 7,000 feet; No. 1224, shrub five feet high, *malpais* south of Uruapan, 5,600 feet.

Solanum longipedicellatum Bitter. No. 1054, barranca four miles east of Tancítaro, 6,000 feet; No. 4021, cloud forest along streams, Cerro Tancítaro.

Solanum nigrum L. Nos. 352, 361, 592, 4020; herb up to five feet high, flowers white; common in damp woods on plateau and up to 8,200 feet in cloud forest.

Solanum polytrichum Rydb. No. 548, the Pedregal, 6,000 feet.

Solanum torvum. Sw. No. 1247, shrub four feet high, *malpais* south of Uruapan, 5,600 feet.

Solanum umbellatum Mill. No. 1246, shrub four feet high, *malpais* south of Uruapan, 5,600 feet.

Solanum verbascifolium L. No. 1434, tree twelve to fifteen feet high, near Hacienda California, thick scrub forest, 1,200 feet.

Solanum verrucosum Schlecht. No. 379, open field one mile south of Tancítaro, 6,000 feet.

SCROPHULARIACEAE

Bacopa Monnieri (L.) Wettst. No. 1435, growing in water, mesic woods near Hacienda California, 1,200 feet; common.

Bacopa procumbens (Mill.) Greenm. No. 524, damp soil, open pasture, north of Tancítaro, 6,500 feet.

Bacopa rotundifolia (Michx.) Wettst. No.1475, growing in outlet of swamp near Hacienda California, 1,200 feet.

Buchnera pusilla HBK. No. 1736, arid canyon, 2,000 feet.

Calceolaria mexicana Benth. Nos. 724, 4023; growing among rocks beside stream, Cerro Tancítaro, 7,500 to 8,200 feet.

Castilleja integrifolia L. Nos. 533, 665, 1210; shrub about four feet high, open pastures and slopes from 6,000 to 10,000 feet; more common in upper part of range from 9,500 to 10,000 feet.

Castilleja lithospermoides HBK. Nos. 664, 683, 684, 1174; common in open pine forest and rocky ridges from 9,500 feet to summit, Cerro Tancítaro.

Castilleja scorzoneraefolia HBK. Nos. 275, 1125; common in open pine forest and rocky ridges from 9,500 to summit, Cerro Tancítaro.

Castilleja tenuiflora Benth. No. 1680, shrub two to four feet high, open pine forest, 3,200 feet.

Conobea pusilla B. & H. No. 1712, herb common in niches in rock along side of canyon, 1,400 to 2,000 feet.

Lamourouxia multifida HBK. No.1116, steep slope below rocky ridge, Cerro Tancítaro, 9,500 feet.

Limosella americana Glück. No. 1221a, growing submerged in two to four inches of water, marshy meadow, north slope of Cerro Tancítaro, 10,500 feet.

Mimulus glabratus HBK. *Hierba de golpe*. Nos. 247, 527; growing in wooden aqueduct in water, two miles north of Tancítaro, 6,500 feet.

Pentstemon campanulatus Willd. Nos. 666, 677, 678, 685; rocky ridges and steep slopes below cliffs, 9,500 to 10,500 feet; very common.

Russelia floribunda HBK. No. 1534, herb or small shrub, flowers scarlet, moist soil in niches in rock near stream, arid canyon, 2,000 feet.

BIGNONIACEAE

Crescentia alata HBK. No. 1595, tree fifteen to thirty-five feet high, occasional on arid slopes below Acahuato up to 2,500 feet; very common on arid plains east of Apatzingan.

Melloa populifolia (DC.). Bur. No. 1360, vine climbing over low trees, flowers yellow, arid scrub forest four miles west of Apatzingan, 1,200 feet.

Taebebuia pentaphylla (L.) Hemsl. No. 1445, tree thirty-five feet high, mesic to arid forest near Hacienda California.

Tecoma stans (L.) HBK. No. 1720, tree eight feet high, spreading, arid canyon, 2,000 feet.

PEDALIACEAE

Sesamum orientale L. No. 464, open fields south of Apatzingan, 1,200 feet.

MARTYNIACEAE

Martynia annua L. Nos. 1405, 1664, common throughout the *tierra caliente*, from 1,000 to 4,000 feet, especially along roadsides, in waste fields, etc.

Martynia arenaria Engelm. No. 485, irrigated field south of Apatzingan.

GESNERIACEAE

Achimenes flava Morton. No. 1253, shallow soil on rock ledges, near Cascada de Tzararacua, seven miles southwest of Uruapan, 6,000 feet.

Achimenes antirrhina (DC.) Morton. No. 1309, flowers scarlet, growing on moist rock in oak forest, road from Uruapan to Apatzingan, 4,000 feet.

Achimenes longiflora DC. No. 1573, flowers purple, growing in niches in rock near stream, arid canyon, 2,300 feet.

Achimenes patens Benth. No. 1616, flowers purple; common on moist stone walls, Acahuato, 3,000 feet.

LENTIBULARIACEAE

Pinguicula caudata Schlecht. No. 396, growing on black, crumbling rock in a damp barranca near Cañada, about 4,000 feet; apparently very localized as to substrata and moisture conditions, also found in deep canyons between Tancítaro and Uruapan at 6,000 feet.

ACANTHACEAE

Barleria micans Nees. No. 1577, shrub one to two feet high, growing in sand beside stream in arid canyon, 2,000 feet.

Dyschoriste ovata (Cav.) Kuntze. No. 613, open pine forest, 5,000 feet.

Elytraria squamosa (Jacq.) Lindau. No. 1536, rocky ledge in shade, arid canyon, 2,000 feet; rare.

Ruellia nudiflora (Engelm. & Gray) Urban. Nos. 407, 1383, common throughout arid scrub forest, 1,200 feet.

PLANTAGINACEAE

Plantago hirtella HBK. Nos. 310, 316; rich alluvial soil along stream near the Pedregal, 6,000 feet.

Plantago mexicana HBK. No. 515, fields throughout the plateau, 6,000 feet; common.

RUBIACEAE

Balmea Stormae Martínez. No. 1229, tree 18 feet high, flowers dark purple, growing in rocky land south of Uruapan, known as *malpais*, 5,600 feet.

Borreria laevis (Lam.) Griseb. Nos. 308, 319, 594, 4001; common herb, growing on open, grassy slopes or in fields throughout the higher parts of the plateau, 6,000 to 7,000 feet.

Borreria suaveolens Mey. No. 4004, grassy hillside near the Pedregal, 6,000 feet.

Borreria verticillata (L.) Mey. Nos. 246, 648; common in open fields and on open slopes throughout the plateau, 6,000 to 7,000 feet.

Bouvardia chrysantha Mart. No. 323, rocky, steep slope in the Pedregal, 6,200 feet.

Bouvardia laevis M. & G. No. 1252, shrub, common in *malpais* south of Uruapan, 5,600 feet.

Bouvardia multiflora (Cav.) Schult. No. 1801, shrub two to three feet high, common in the pine forest from 3,000 to 4,000 feet.

Crusea coccinea DC. Nos. 350, 694, 1082; vine, flowers scarlet, growing in deep barrancas, along streams, and in shady, damp situations up to 7,000 feet.

Cephalanthus salicifolius H. & B. No. 1593, shrub or small tree, growing in or near water, common along the Río Apatzingan up to 3,000 feet or higher.

Chiococca alba (L.) Hitchc. No. 1796, tree fifteen feet high, edge of stream, Las Barranquillas, 4,000 feet.

Deppea tenuiflora Benth. No. 1264, shrub three to four feet high, near the Cascada de Tzararacua, southwest of Uruapan, 6,000 feet.

Didymaea alsinoides (S. & C.) Standl. Nos. 338, 730, 1185; probably the commonest vine of the dense fir forest above 8,200 feet, usually prostrate and creeping but may be climbing on rocky ledges or trees and shrubs, 7,800 to 9,000 feet or higher.

Diodia teres Walt. No. 1654, rocky soil, open pine forest above Uruapan, 3,200 feet.

Galium Aschenbornii Schauer. No. 1622, shaded, rocky ledge in barranca, Acahuato, 3,000 feet.

Galium mexicanum HBK. Nos. 663, 1124; vine climbing on small trees, Cerro Tancítaro, 9,300 feet.

Guettarda elliptica Sw. No. 1411, tree fifteen feet high, arid scrub forest four miles west of Apatzingan, 1,200 feet; No. 1677, shrub ten feet high, growing in shade on the side of a barranca, along trail from Apatzingan to Tancítaro, 3,200 feet.

Hamelia xorullensis HBK. No.1420, shrub three feet high, damp ravine, La Cañada, 4,000 feet; No. 1564, tree fifteen feet high, growing beside stream in a canyon below Acahuato, 2,000 feet; No. 1644, shrub seven feet high, open pine forest, 3,200 feet.

Hintonia latiflora (M. & S.) Bullock. No. 1553, tree eighteen feet high, flowers greenish-white, sweet-scented, arid scrub forest near La Majada, west of Apatzingan, 1,200 feet; only one specimen seen.

Psychotria microdon (DC.) Urb. No. 401, tree ten to fifteen feet high, growing beside the Río Apatzingan two miles south of Apatzingan, 1,200 feet.

Psychotria papantlensis (Oerst.) Hemsl. No. 1460, dense mesic forest near Hacienda California, 1,200 feet.

Randia echinocarpa M. & S. *Crucillo*. Nos. 1398, 1537, 1763, small tree or shrub up to fifteen feet high, trunks twisted and twining; very common throughout arid parts of the tropical zone, 1,000 to 2,500 feet.

Randia laetevirens Standl. *Crucillo*. No. 1429, shrub four to five feet high, thick transition forest near Hacienda California, 1,200 feet.

Randia malacocarpa Standl. No. 467, tree six to ten feet high, mesic forest near Río Apatzingan, two miles south of Apatzingan, 1,200 feet.

Randia Nelsonii Greenm. Nos. 1470, 1517, 1555; tree twenty to thirty-five feet high, common in arid scrub and transition scrub forests, becoming very common on arid slopes from 1,200 to 2,000 feet.

Randia Watsoni Rob. No. 470, shrub four to six feet high, growing in the thick transition scrub forest near the Río Apatzingan, two miles south of Apatzingan; common in arid scrub forest.

Richardia scabra L. No. 1292, rocky pasture land west of Uruapan, 6,000 feet; common.

CAPRIFOLIACEAE

Viburnum Loeseneri Graebner. No. 523, shrub five feet high, open pine forest north of Tancítaro, 6,500 feet; No. 646, tree ten to fifteen feet high, growing beside stream near trail from Tancítaro to Apatzingan, pine forest, 5,000 feet.

Viburnum microphyllum (Oerst.) Hemsl. No. 671, tree ten to fifteeen feet high, rocky ridge on Cerro Tancítaro at about 9,500 feet; rare.

VALERIANACEAE

Valeriana scorpioides DC. No. 1254, herb, flowers white, *malpais* south of Uruapan, 5,600 feet; common in open situations.

CUCURBITACEAE

Cyclanthera dissecta Naud. No. 565, in partial shade, the Pedregal, 6,000 feet.

Cyclanthera Langaei Cogn. No. 728, vine climbing on trees and shrubs in cloud forest, Cerro Tancítaro, 8,000 feet.

Cyclanthera pedata Schrad. Nos. 357, 4037; vine climbing on trees and shrubs in damp cloud forest near stream in dense undergrowth, 8,000 feet.

Maximowiczia tripartita (Naud.) Cogn. No. 1437, climbing on small trees to a height of fifteen feet, dense transition scrub forest near Hacienda California, 1,200 feet.

Melothria scabra Naud. Nos. 1617, 1831; climbing over rocks on open ridges above Acahuato, 3,200 feet.

Momordica Charantia L. No. 417, vine climbing over small trees, flowers yellow, fruit bright orange, tuberculate, bright red inside, bank of Río San Antonio near Rancho El Capiri.

LOBELIACEAE

Lobelia fenestralis Cav. Nos. 369, 1793; very common herb in fields south of Tancítaro, 6,000 feet; one specimen found beside stream at 4,000 feet.

Lobelia laxiflora HBK. Nos. 348, 4015, 4038; shrub five to fifteen feet high, flowers orange-red, very conspicuous, fairly common but not abundant from the altitude of 6,000 feet or lower to above 8,500 feet; usually grows in fields or in the partial shade along the borders of fields and woods, but plants were found growing in dense shade of the cloud forest.

COMPOSITAE

Achaetogeron affinis Gray. Nos. 279, 1156, 1176; Cerro Tancítaro, common on open, grassy slopes above 10,500 feet, very abundant on the north slope of the mountain.

Ageratum corymbosum Zucc. No. 1813, flowers light blue, on the rocky side of a barranca, near Las Barranquillas, 3,800 feet.

Aphanostephus ramosissimus DC. Nos. 375, 384; open fields south of Tancítaro, 6,000 feet; common.

Archibaccharis hirtella (DC.) Heering. No. 1090, moist soil, deep barranca, Cerro San Miguel, 6,700 feet.

Astranthium purpurascens (Rob.) Larsen. No. 649, near the trail from Tancítaro to Apatzingan, 5,000 feet.

Baccharis glutinosa Pers. No. 580, shrub ten feet high, forming dense thickets along the edges of a field beside the Pedregal, 6,000 feet.

Baccharis heterophylla HBK. No. 1046, shrub six feet high, common along streams near the Pedregal, 6,000 feet.

Baccharis ramulosa (DC.) Gray. No. 535, small shrub, very common in pastures from 6,000 to 7,000 feet. The branches are used by the Indians for sweeping.

Baccharis thesioides HBK. No. 1786, shrub three feet high, open pasture near stream, Las Barranquillas, 4,000 feet; a common shrub in pastures and open woods up to 7,000 feet or higher.

Bidens aequisquama (Fern.) Sherff. No. 333, flowers purple, open meadow north of Tancítaro, 6,500 feet; No. 612, three to four feet high, open pasture along trail from Tancítaro to Apatzingan, 5,500 feet; not common.

Bidens ostruthioides (DC.) Sch. Bip. Nos. 662, 1081, 4022, 4031; vine, flowers yellow, common in spruce forest and above to 10,000 feet, Cerro Tancítaro, also common in pine forest on Cerro San Miguel.

Bidens Pringlei Greenm. No. 1242, flowers white, *malpais* south of Uruapan, 5,600 feet; not common.

Bidens triplinervia HBK. Nos. 679, 1120; flowers yellow, common on rocky ridges on Cerro Tancítaro from 9,500 feet nearly to the summit.

Brickellia paniculata (Mill.) Rob. Nos. 1646, 1700; shrub two to six feet high, open pine forest above Acahuato, 3,200 feet.

Cacalia Palmeri Greene. Nos. 539, 542a, 639; flowers white; common in open pastures from 6,000 to 7,200 feet.

Cacalia peltata HBK. Nos. 1167, 1214; Cerro Tancítaro, common in moist soil in the cloud forest along streams and on rocky ridges up to 10,000 feet.

Calea urticaefolia (Mill.) DC. No. 1827, shrub three to five feet high, common in pine forest from 3,200 to 3,800 feet.

Cirsium jorullense (HBK.) Spreng. Nos. 700, 1179, 1166; plant usually two to four

feet high, flowers magenta, common on rocky ridges, found occasionally in open parkland, Cerro Tancítaro, 9,500 to 10,500 feet or higher.

Cirsium acantholepis (Hemsl.) Petrak. No. 4026, about three feet high, cloud forest, 8,000 feet.

Cirsium nivale (HBK.) Sch. Bip. No. 1180, flowers purple but heads appearing white from the dense tomentum of the involucre, plants one to two feet tall, found only on the north side of Cerro Tancítaro, from about 11,000 feet to near the summit; common.

Conyza coronopifolia HBK. No. 377, open field one mile south of Tancítaro, 6,000 feet.

Cosmos carvifolius Benth. No. 998, pine forest, near Rancho Santa Catarina, 6,000 feet.

Cosmos parviflorus HBK. No. 371, open field, one mile south of Tancítaro, 6,000 feet.

Cosmos sulphureus Cav. No. 1641, very common in cultivated fields near Acahuato, 3,200 feet.

Dahlia coccinea Cav. Nos. 590, 640; plants four to six feet high, flowers brilliant orange-red, moist, shady woods, usually among rocks, often growing on stone walls; common from 3,200 up to 7,200 feet or higher, but never abundant.

Dahlia Merckii Lehm. Nos. 273, 688, 1130; common in clefts of rocky, wet cliffs on Cerro Tancítaro, above 9,500 feet.

Eclipta alba (L.) Hassk. No. 489, growing in muck in an irrigation ditch, Apatzingan, 1,200 feet.

Erigeron Karvinskyanus DC. No. 314, shady places in the Pedregal, 6,000 feet; No. 1055, growing on an overhanging dirt bank in a moist barranca four miles east of Tancítaro; common, 6,000 feet.

Erigeron scaposus DC. No. 534, waste field north of Tancítaro, 6,500 feet.

Eupatorium Aschenbornianum Schauer. No. 1160, flowers white, involucre pinkish, open ridges, above 9,500 feet, Cerro Tancítaro.

Eupatorium Mairetianum DC. Nos. 1193, 1200, 1203; shrub up to fifteen feet high, branches long and drooping, common in cloud forest from 8,200 to 9,500 feet, Cerro Tancítaro.

Galeana pratensis (HBK.) Rydb. No. 1296, open pasture west of Uruapan, very common, 6,000 feet; No. 1630, open pine forest and rocky fields above Acahuato, 3,200 feet.

Galinsoga ciliata (Raf.) Blake. No. 1299, open pasture west of Uruapan, 6,000 feet; very common.

Gnaphalium attenuatum DC. No. 1064, growing abundantly in moist soil in yard at Tancítaro, 6,000 feet.

Gnaphalium oxyphyllum DC. No. 1149, Cerro Tancítaro, cliff, 11,000 feet; common in open, grassy parkland and on rocky cliffs up to the summit.

Gnaphalium spathulatum Lam. No. 1173, in marshy meadow, north side of Cerro Tancítaro, 10,500 feet; not common.

Gnaphalium Sprengelii Hook. & Arn. No. 1152, common on rocky ledges near peak, 11,000 feet, Cerro Tancítaro.

Guardiola tulocarpa Gray. No. 1686, shrub four feet high, flowers white; common in open pine forest, 3,200 feet.

Helenium ooclinium Gray. No. 488, open pasture south of Apatzingan, 1,200 feet.

Heliopsis annua Hemsl. No. 462, mesic forest near Rio Apatzingan, south of Apatzingan, 1,200 feet.

Heliopsis parviceps Blake. No. 1370, common herb in open woods, yellow heads with black center, semi-desert scrub 4 miles west of Apatzingan, 1,200 feet.

Heterotheca subaxillaris (Lam.) Britt. & Rusby. No. 262, common locally in pastures throughout plateau, 6,500 feet; known locally as *árnica*.

Hieracium abscissum Less. No. 596, the Pedregal, 6,000 feet; No. 1137, open pine forest, Cerro Tancítaro, above 9,500 feet; fairly common.

Jaegeria macrocephala Less. No. 1137, creeping herb in swamp, pine forest, 5,000 feet.

Jaegeria hirta (Lag.) Less. No. 1300, open pasture west of Uruapan, 6,000 feet.

Liabum glabrum Hemsl. No. 670, shrub eight to ten feet tall, Cerro Tancitaro, about 9,500 feet.

Melampodium americanum L. Nos. 387, 1298, 1567, 1589; common on arid slopes from 1,200 to 3,000 feet, and in open pine forest up to about 4,000 feet.

Melampodium divaricatum (L. Rich.) DC. Nos. 374, 457, 1333, 1337; common herb in the mesic forests of the river valley, found throughout the pine forest up to the plateau at 6,000 feet.

Melampodium linearilobum DC. No. 1480, arid slopes from 1,200 up to 2,500 feet; common locally.

Melampodium oblongifolium DC. No. 1631, open pine forest, 3,200 feet.

Melampodium sericeum Lag. No. 1653, open, rocky pastures above Acahuato, 3,200 feet; common.

Pectis imitans Standl., sp. nov.

Perennis erecta fere 30 cm. alta, basi lignescens, ubique sat dense ramosa, densiuscule foliata, caulibus gracilibus rigidis teretibus glabris, interdum purpurascentibus; folia numerosa, anguste linearia, rigidiuscula, adscendentia, plerumque 1.5-3 cm. longa, 0.5 mm. lata, apice pungenti-setulosa, prope basin utroque latere setoso-ciliata, glabra, 1-nervia, utroque latere linea singula glandularum parvarum manifestarum onusta; capitula parva numerosa, terminalia et lateralia, pedicellis filiformibus glabris erectis 3-4 cm. longis; phyllaria 5 glabra ca. 5 mm. longa, oblongo-spathulata, acuta vel obtusa, vix ciliata; flores ca. 6, phyllariis 2-2.5 mm. longiores; corollae filiformi-tubulosae 4-4.5 mm. longae, glabrae, lobis brevibus; flores disci steriles; achaenia vulgo 3, turbinato-linearia, ca. 3 mm. longa, glabra; pappi setae 5-6, filiformes, basi vix dilatatae, 4 mm. longae, erectae.

MEXICO: Michoacán: Arid sides of canyon below Acahuato, Municipalidad Apatzingan, alt. 2,500 ft., common, the flowers yellow, August 15, 1941, William C. Leavenworth & H. Hoogstraal 1563 (type in Herb. Chicago Nat. Hist. Mus.).

This plant does not fall satisfactorily into Rydberg's key to the species of *Pectis* in *North American Flora*. There it would, apparently, run at once to *P. imberbis* Gray, a more northern species with much larger flower heads, and very different in habit. It is excluded from the other arm of the key, which contains most of the species of the genus, by the very slender pappus setae, which scarcely can be considered as "squamellae" in any sense of that word. The plant is well marked by its half-shrubby habit, from a hard woody base, and by the very slender, stiff, exceptionally narrow leaves, which have a conspicuous row of numerous close glands along each side.

Pectis Leavenworthii Standl., sp. nov.

Herba perennis, e radice lignescente nascens, caulibus prostratis vel asdscendentibus, usque ad 23 cm. longis, rigidiusculis, simplicibus vel sparse erecto-ramosis, sat dense foliatis, interdum purpurascentibus, internodis plerumque foliis brevioribus, dense puberulis vel hispidulis; folia patentia rigidiuscula, lineari-oblonga vel lineari-lanceolata, plerumque 1.5-2 cm. longa, 3-4 mm. lata, apice obtusa vel subrotundata et setifera, basi utroque latere setis paucis elongatis pallidis aucta, canescentia, glabra, 1-nervia, costa utrinque prominente, marginibus cartilagineo-incrassatis atque pallidis; capitula terminalia, longipedicellata, singula, pedicellis usque ad 5 cm. longis erectis, dense albo-puberulis; phyllaria 5, late spathulato-obovata, 7-9 mm. longa, ciliata, pallida, glabra, apice subtruncata vel rotundata, marginibus scariosis saepe purpureo tinctis, sparse glandulosa; flores radiiferi 5, ligulis anguste oblongis, ca. 1 cm. longis, floribus disci paucis, corollis 5-6 mm. longis, glabris; achaenia nigrescentia, anguste columnaria, 4-4.5 mm. longa, dense puberula; squamellae pappi florum disci 2, spathulato-oblongae, apice rotundatae vel obtusissimae, albidae.

MEXICO: Michoacán: Arid slope above Apatzingan, herb with yellow flowers, alt. 2,000 ft., August 13, 1941, William C. Leavenworth & H. Hoogstraal 1485 (type in Herb. Chicago Nat. Hist. Mus.). Above Apatzingan, 2,000 ft., common, August 7, 1940, Leavenworth 509.

The closest relative of the present species is *Pectis propetes* Greenm., described from Zacatecas and collected also in Guerrero. That is described as an annual, and differs

in having the stems pubescent only in lines, rather than densely puberulent on all sides, much shorter rays, and lance-acuminate pappus scales.

Pectis liniifolia L. No. 1504, arid slopes of Cerro Apatzingan, about 1,300 feet; common.

Pectis prostrata Cav. No. 1307, rocky pasture two miles west of Uruapan, 6,000 feet.

Perymenium Berlandierii DC. No. 1208, shrub eight or ten feet high, open cliff, Cerro Tancítaro, 9,500 feet, not common; No. 1660, tree ten feet high, open pine forest above Acahuato, 3,200 feet.

Perymenium flexuosum Greenm. Nos. 611, 1802; pine forest at 3,500 and 5,000 feet.

Pinaropappus roseus Less. No. 383, open field one mile south of Tancítaro, 6,000 feet.

Piqueria pilosa HBK. Nos. 289, 694a, 703, 1209, 4043; found in open situations from the plateau at 7,000 feet up to 10,000 feet or higher on Cerro Tancítaro; commonest on damp slopes below cliffs at about 10,000 feet.

Piqueria trinervia Cass. No. 245, open pasture north of Tancítaro, 6,500 feet.

Porophyllum nutans Rob. & Greenm. Nos. 1552, 1572; shrub four or five feet tall; common on steep, arid slopes of canyons, 1,500 to 2,500 feet.

Sabazia Liebmanii Klatt. No. 682, growing in shaded situations under alder, moist slopes below cliffs, Cerro Tancítaro, 10,000 feet.

Sabazia sarmentosa Less. No. 392, open pine forest, about 4,500 feet.

Salmea Palmeri Wats. Nos. 1647, 1696, 1702; shrub three to five feet high, common on open, rocky hillsides above Acahuato, 3,200 feet.

Sclerocarpus uniserialis (Hook.) B. & H. Nos. 1522, 1575; common on arid slopes from 2,000 to 3,000 feet.

Senecio calcarius HBK. No. 1151, common on well drained cliffs from 10,500 feet to summit, Cerro Tancítaro.

Senecio platanifolius Benth. No. 1205, shrub eight feet high, very common in the cloud forest beside streams on Cerro Tancítaro from 7,000 to 10,000 feet. In the lower part of its range it often reaches a height of fifteen or twenty feet and forms solid, dense stands wherever the tree cover allows enough light to come through.

Senecio salignus DC. Nos. 341, 589; shrub or small tree six to twelve feet tall, flowers yellow, fairly common along the borders of fields from 6,000 feet or lower up to 8,000 feet.

Senecio Sanguisorbae DC. Nos. 650, 722; herb up to twelve feet high, abundant locally in marshy places and beside streams up to 7,300 feet.

Stevia jorullensis HBK. No. 1216, rocky ledges, Cerro Tancítaro, 10,000 feet; common.

Stevia lucida Lag. Nos. 690, 1121, 1201, 1202, 1211; shrub two to twelve feet high, common on rocky ledges from 9,500 to 10,000 feet or higher, Cerro Tancítaro.

Stevia rhombifolia HBK. No. 1129, rocky ledge, 10,500 feet, Cerro Tancítaro; No. 1670, open slopes above Acahuato, 3,200 feet; No. 1822, pine forest, 3,500 feet, common.

Tragoceros Schiedeanus Less. No. 435, arid scrub forest near Rancho El Capiri, 1,000 feet.

Tridax procumbens L. Nos. 504, 1479; very common on open, lower slope of Cerro Apatzingan, about 1,500 feet.

Trigonospermum hispidulum Blake. No. 549, plant about four feet tall, the Pedregal, 6,000 feet.

Trixis hyposericea Wats. No. 1524, shrub four feet high, arid canyon below Acahuato, 1,500 feet.

Trixis longifolia Don. No. 1734, shrub two feet high, open arid slopes from 2,500 to 3,000 feet.

Verbesina Greenmanii Urban. No. 1225, shrub fifteen feet high, *malpais* south of Uruapan, 5,600 feet; No. 1782, shrub ten feet high, pine forest above La Presa, 3,600 feet; fairly common from 3,000 to 5,000 feet or higher.

Verbesina tetraptera DC. Nos. 1667, 1805; herb up to four feet high, open, rocky slopes above Acahuato, 3,200 feet.

Vernonia Deppeana Less. No. 1230, tree five feet high, *malpais* south of Uruapan, 5,600 feet.

Zexmenia crocea Gray. No. 1692, shrub three to four feet tall, flowers brilliant orange, open slopes above Acahuato, 3,200 feet.

Zexmenia helianthoides (DC.) Gray. No. 1669, shrub two to three feet high, open pine forest above Acahuato, 3,200 feet.

Zexmenia hispida (DC.) Gray. No. 1576, shrub about two feet high, arid slopes, 2,500 feet.

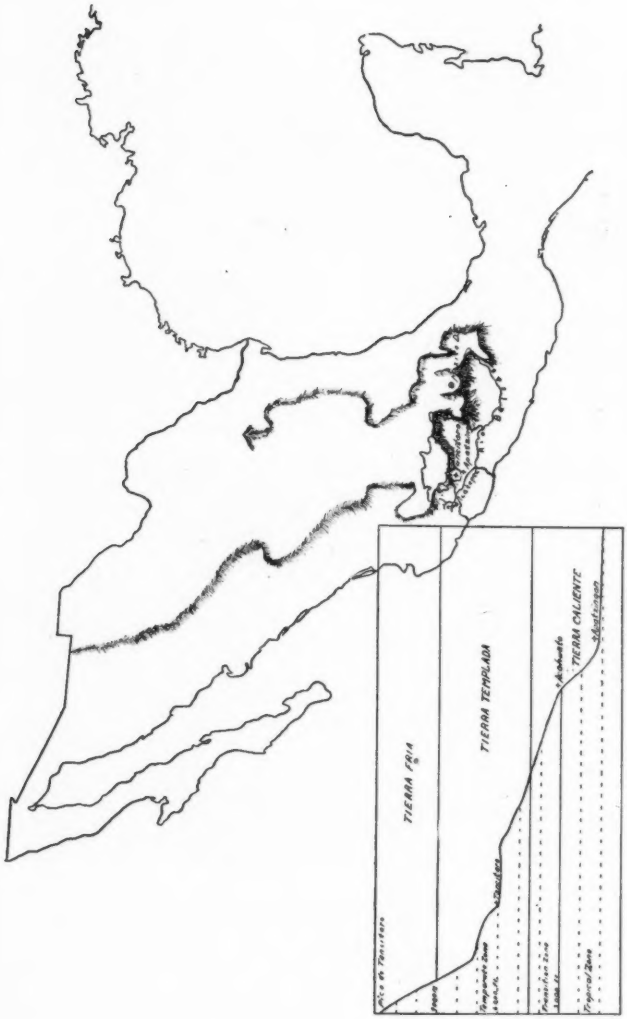
Zinnia angustifolia HBK. No. 1818, open pine forest, 3,500 feet; fairly common.

Zinnia linearis Benth. No. 391, open pine forest, 4,000 feet.

Zinnia maritima HBK. Nos. 510, 1488, 1579; open, arid slopes from 1,200 to 3,000 feet; very common.

ACKNOWLEDGMENTS

A great deal of the credit for this work is due to Mr. Harry Hoogstraal, whose industry and initiative have made the expeditions possible, and whose observations and suggestions have proved indispensable in the preparation of this article. The authors wish to thank Mr. Paul C. Standley and Dr. J. A. Steyermark, who identified the greater part of the collections. Mrs. Agnes Chase has very kindly identified all the grasses, and the complete set of grasses is in the U. S. National Herbarium. Dr. Muller of the U. S. Bureau of Plant Industry determined the oaks of the first summer's collection. Mr. E. B. Bartram, of Bushkill, Pennsylvania, was very kind to determine the mosses and is to be thanked for the description of a new species. Further thanks are due to Dr. Louis O. Williams of Harvard University for the identification of several orchids, to Dr. W. R. Maxon for some of the ferns, to Dr. Carl Epling for the determination of some species of *Salvia*, to Mr. C. V. Morton, to Dr. Lincoln Constance of the University of California, to Dr. B. G. Schubert of the Gray Herbarium, and to Dr. H. K. Svenson of the Brooklyn Botanical Garden. Acknowledgments are made also to Mrs. W. C. Leavenworth, who acted as field secretary during the second trip.



Map showing the position of the Tanc.-Apatz Region to the rest of Mexican and to the Mesa Central.

Fig. 1 (upper).—The summit of Cerro Tancítaro. Notice that although the pines in the foreground are slightly dwarfed, those in the distance show no effect of the altitude.

Fig. 2 (lower).—On the grassy slopes just below the peak *Cirsium nivale* is found in abundance. With it can be seen *Achaetogeron affinis, Habenaria limosa, Muhlenbergia virescens,* and another grass.

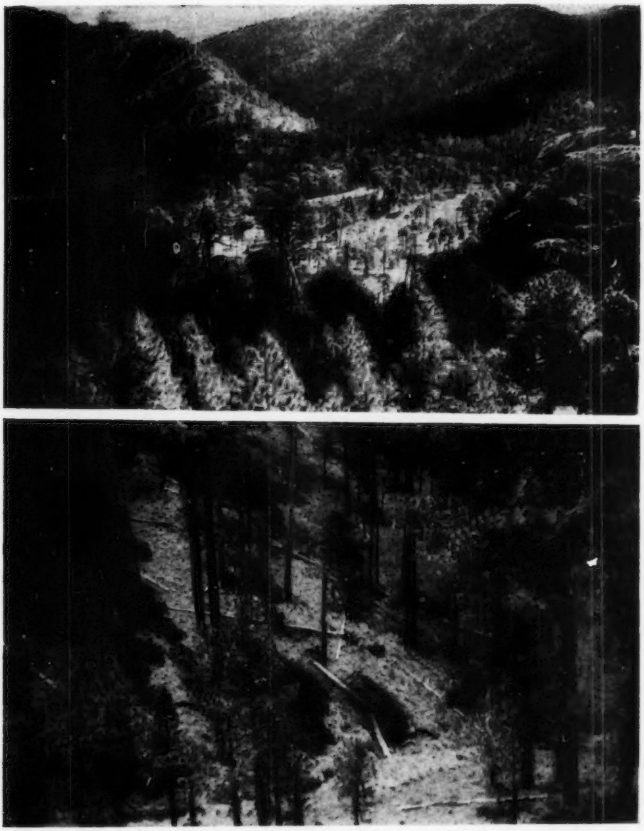


Fig. 3 (upper).—Looking northward from a ridge near the summit. The open pine parkland shown in this scene covers almost the entire mountain above an altitude of about 9,500 feet.

Fig. 4 (lower).—Near the head of a stream valley at 10,500 feet. This view, taken from the camp, shows the open character of the pine parkland at close range.

Fig. 5 (left).—A stand of alder at 9,800 feet. *Alnus arguta* is common on moist slopes above 9,500 feet, where it forms an important constituent of the mixed forest parkland. Above about 10,000 feet it is replaced entirely by pine. Fig. 6 (right).—Immediately above the cloud forest many of the trees are heavily covered with epiphytes, mostly lichens and ferns. The alder shown here was growing at an elevation slightly above 9,500 feet.

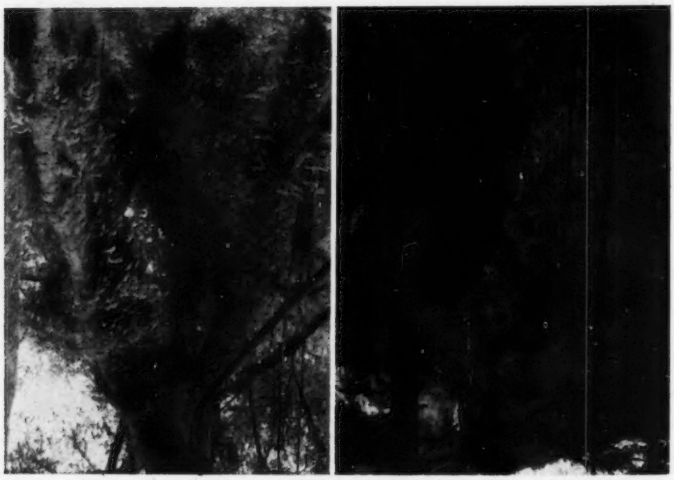


Fig. 7 (right).—Cloud forest at 9,000 feet. *Abies religiosa* forms solid stands on the

Fig. 9 (upper).—*Polypodium angustifolium* growing on *Quercus calophylla*, Cerro San Miguel, 6,700 feet. Most of the larger oaks on the plateau bear some epiphytic pteridophytes, but they lack the heavy bryophytic covering characteristic of the trees in the cloud forest.

Fig. 10 (lower).—A protected basin in the Pedregal, an extensive region of upturned volcanic rocks. The fern at the left is *Polypodium aureum*, the small tree with white flowers, *Coulterophytum Holwayi*, and the shrub on the extreme right, *Clusia Salvinii*.

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steep sides of valleys at this elevation. A few shrubs and herbs grow in the dense shade of the fir forest, but lichens and mosses are the most conspicuous element of the vegetation. Fig. 8 (left).—A view of the cloud forest at 7,800 feet. At this elevation the trees are heavily festooned with hepatics, mosses, and ferns. The trees here are *Meliosma dentata* and *Quercus laurina*.

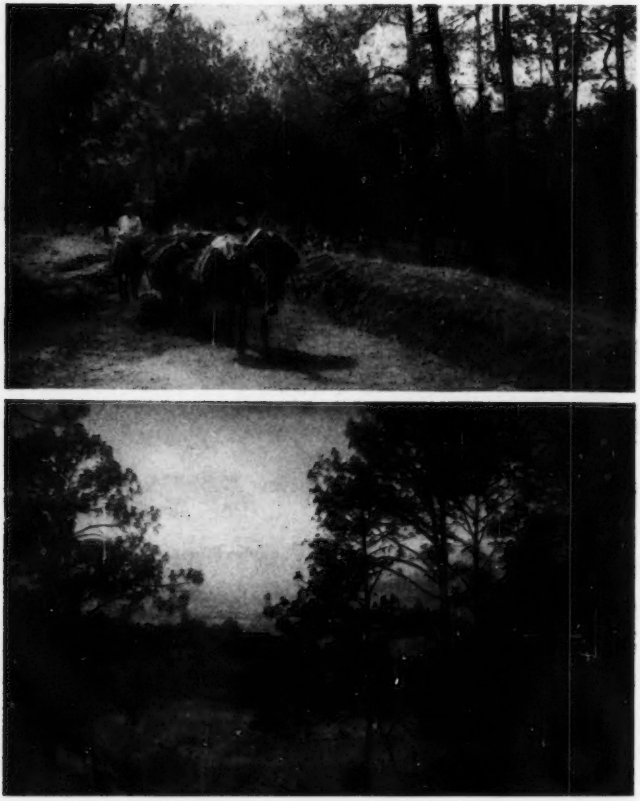

Fig. 11 (upper).—A view of the open pine forest east of Tancítaro, at an elevation of about 6,000 feet. The parts of the plateau which are not under cultivation are covered for the most part by a similar open type of forest.

Fig. 12 (lower).—The lower limit of the pine forest, at 3,000 feet. In the right and left foreground are specimens of *Annona longiflora* and in the slopes below can be seen the upper limit of the arid scrub forest. In the background is the Sierra Madre del Sur.

Fig. 13 (upper).—The homogeneous character of parts of the forest on the arid slopes below 3,000 feet is shown in this photograph. The trees in the background are almost entirely *Pseudosmodingium perniciosum*.

Fig. 14. (lower).—A closer view of the same type of forest as the above. *Pseudosmodingium perniciosum* in an almost solid stand on Cerro Apatzingan, 1,400 feet.

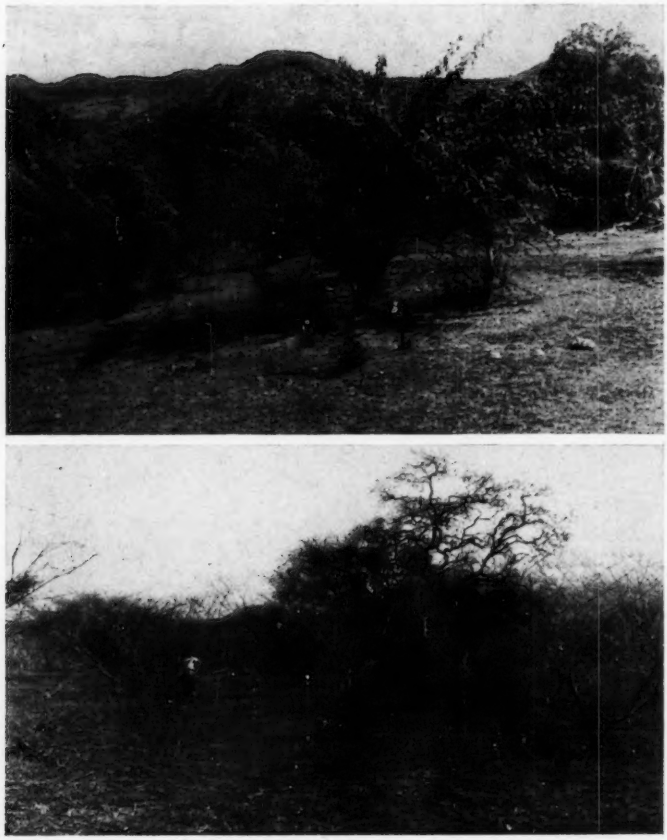

Fig. 15 (upper).—View of the open arid scrub forest near Apatzingan. The trees in the foreground are *Randia echinocarpa*.

Fig. 16 (lower).—The arid scrub forest near Rancho El Capiri on the Río Tepalcatepec. The trees here are almost entirely *Acacia cymbispina*. The large one to the right is *Zizyphus sonorensis*, one of the most widespread species in the arid scrub forest.

Fig. 17 (upper).—A colony of *Acanthocereus pentagonus*. This cactus, often associated with *Pachycereus pecten-aboriginum*, is common locally throughout the arid scrub forest, particularly in the vicinity of the river.

Fig. 18 (lower).—This giant *Opuntia* is a prominent species of the arid slopes between 1,200 and about 1,400 feet. It is abundant on the lower slopes of Cerro Apatzingan, where this photograph was taken.

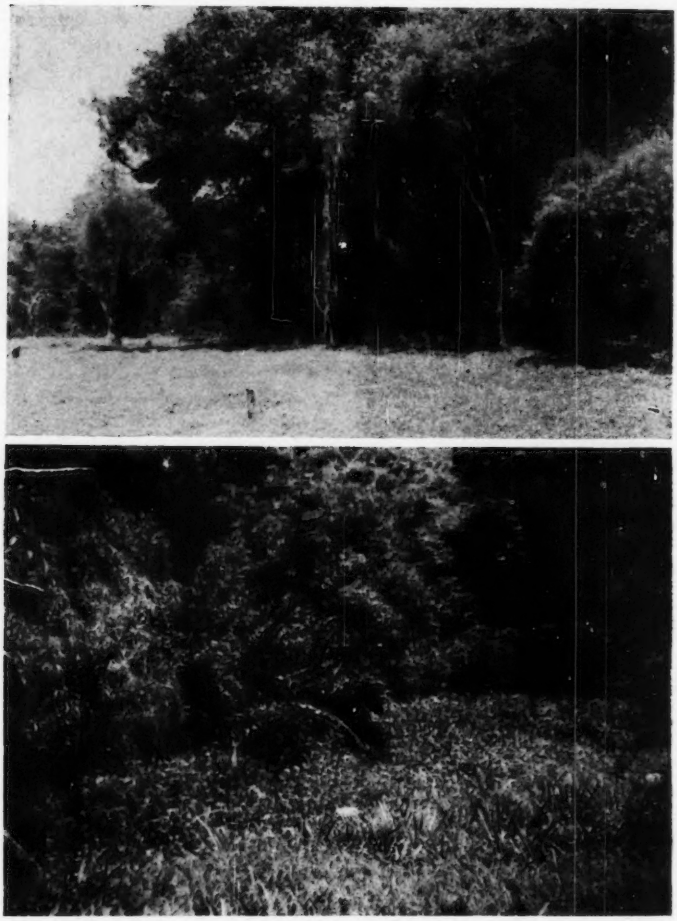

Fig. 19 (upper).—Tropical deciduous forest south of Apatzingan. Near the streams or in low areas where there is an adequate supply of ground water flourishes a forest of large mesic species, among them *Sideroxylon*, *Calocarpum*, *Trichilia*, *Brosimum*, and several species of *Ficus*.

Fig. 20 (lower).—A swamp in the thick tropical deciduous forest near La Majada. Where low-lying areas are not yet drained, flourish the remnants of once impenetrable swamps. The large fern on the left is *Acrostichum danaeafolium*, *Eichhornia azurea* forms a solid mat on the surface of the water, and around the edge (foreground) is *Pancratium littorale*.

Studies in the Trigonocarpales. Part I. Pachytesta vera, a New Species from the Des Moines Series of Iowa

J. H. Hoskins and A. T. Cross

CONTENTS

Material, Horizon and Methods

While observing the mining operations in the large Angus strip pit near Oskaloosa, Mahaska County, Iowa, one of many coal balls exposed was broken by the steam shovel and the resultant fresh surface revealed the outline of a large seed. The remainder of the coal ball was not recovered. Subsequent examination of the petrifaction disclosed two more or less complete seeds and a portion of a third. The juxtaposition of these seeds strongly suggests a natural grouping. However, no proof of physical connection exists.

This deposit of coal balls occurs in a coal of the Des Moines Series. No exact correlation is yet available. Tentative assignment is to the base of the Allegheny Formation (Hoskins and Cross, 1943, fig. 40).

After the orientation of the seeds within the coal ball was determined, they were sectioned by the wire cutting technique to show critical areas. The best of the seeds (Seed No. I) was sectioned as shown in figure 3. Altogether, 19 surfaces, mostly longitudinal or transverse were studied by the peel method. Serial peel-sections taken from all surfaces total approximately 400, of which about 300 were mounted[1], 20-58 peels being removed from single surfaces in critical areas.

Figure 3 also shows diagrammatically the comparison of the amount lost in the kerf of the thin diamond saw used in preliminary sectioning and the amounts lost in subsequent cuts by the wire cutting method. Since even

1 It appears that the synthetic resin, Diaphane, used as a mounting medium for a number of the peels has a deleterious effect on the prepared peel which is noticeable only after several months.

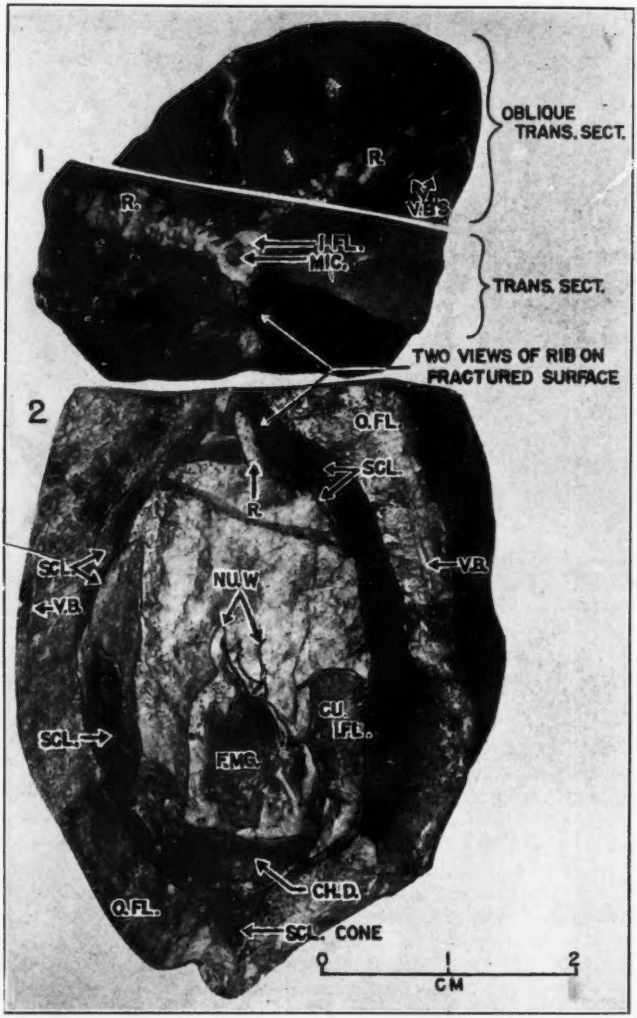

Fig. 1.—Transverse and obliquely transverse section through Seed No. I at the level of the top of Fig. 2. White areas of the ribs (R.) and the inner fleshy zone (I.F.L.) are calcite. The circular micropylar opening (MIC.) is evident.

Fig. 2.—Longitudinal view of fractured surface exposing successively deeper tissues of the seed toward the center.

the thinnest saw removes an appreciable portion of the specimen, whole critical areas can easily be lost by its unrestricted use. Polished or etched surfaces studied by reflected light were employed on occasion but were not a satisfactory substitute for peels. In the more critical regions it was deemed inadvisable to destroy any material in preparation of thin sections, but elsewhere, the adequacy of peels was checked against thin ground rock-sections.

Organization of Seed

The seed[2] is smooth, ovoid, radially symmetrical, 6.5 cm. in length and has a maximum diameter of about 3.5 cm. Seed No. I was preserved near the center of the calcareous coal ball, with little distortion, both base and apex intact, and with little loss of investing tissues. Seed No. II occurred near one side of the coal ball and is less well preserved.

The seed possesses a single thick integument, composed of an outer fleshy layer, a well-defined stony layer and a thin inner fleshy layer. The radial extensions of the stony layer form three major longitudinal ribs which extend from the base of the seed to the tip of the micropyle. The effect of these ribs is shown in the well known triradiate character of Trigonocarpus. The micropyle is short, extending not more than one-fourth the total length of the seed.

A single large vascular bundle enters the base of the seed and branches to form a double vascular system supplying both the integument and the nucellus. The nucellus is free from the integument throughout and is conspicuously stalked. The apex is broadly rounded and centrally forms a short nucellar "beak" which extends into the base of the micropylar opening. Within the nucellus is a large megaspore membrane (embryo-sac). In the area between the megaspore membrane and the dome-like distal end of the nucellus (pollen-chamber) occur both non-functional megaspores in tetrahedral groups and numerous pollen grains with inflated bladders.

In general structure this seed corresponds to those described by Brongniart (1874a, 1874b, 1881), Renault (1893, 1896) and Reed (1939) as Pachytesta, and by Hooker and Binney (1855), Williamson (1877), Scott and Maslen (1907), Salisbury (1914) and others as Trigonocarpus. A consideration of the relationships between Pachytesta and Trigonocarpus will be presented in Part II of this paper.

Structure of Seed

Integument

Outer Fleshy Layer

The outer fleshy layer (= sarcotesta of Scott and Maslen, and Salisbury and others; = exotesta of Brongniart, Renault and Oliver) is the conspicuous zone of parenchyma tissue which forms the bulk of the integument. It is remarkably uniform in thickness from the base of the seed up to the micropylar area. At this level it increases rapidly from the normal thickness of about 4.5 mm. to 8 mm., above which it tapers off to the apex of the seed (figs. 3, 52).

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2 We shall use the term "seed" for the advanced stage of ovular development of the fossils discussed in this paper.

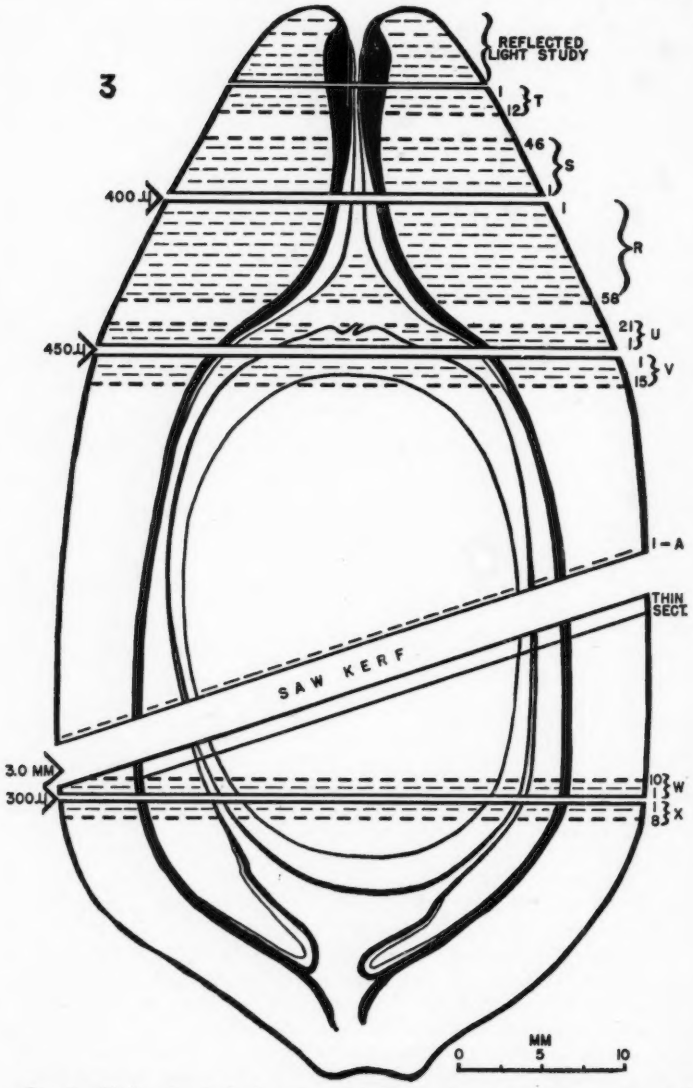

Fig. 3.—Median longitudinal section of holotype plotted to scale showing actual arrangement of tissues. The position and amount of material lost in the five transverse cuts of this seed is indicated at left. The number of peels, their position and amount of material included in each series is shown at right.

It is bounded externally by a definite epidermis which consists of a layer of small, uniform, somewhat cuticularized cells (figs. 15, 16). In both longitudinal and transverse sections they appear uniform, the radial walls measuring 40μ, and the tangential walls 18-28μ. The walls are 5-8μ in thickness, nearly double those of the parenchyma cells immediately subjacent. Beneath the epidermis 3-5 rows of small cells appear transitional to the larger normal cells of the outer fleshy layer. It is the epidermis and this outer layer of cells only which have frequently undergone deterioration before preservation. This observation is substantiated by the remarkable uniformity of the outer fleshy layer throughout the seed and the negligible difference in thickness between those areas where the epidermis is well preserved and where it is absent.

The outer fleshy layer is composed principally of loose and fairly uniform, isodiametric cells, averaging 85μ in short diameter. Toward the periphery the cells are somewhat larger than the average, i.e., 100-225μ in greatest diameter by about 65μ. They are compact, with few intercellular spaces, especially toward the inner part. The walls are relatively thin but firm. There is some reduction in size of the cells in particular regions such as (a) adjacent to the vascular bundles, which traverse the outer fleshy layer, (b) adjacent to the radial extensions of the stony layer which form the ribs, and (c) near the periphery of the seed.

Secretory cells or canals are present sparingly. This will be discussed in detail later. The outer fleshy layer is traversed by a number of vascular strands. Their nature and occurrence is taken up in the discussion of the vascular system of the seed. There is no layer of stony cells in the outer region of the outer fleshy layer.

STONY LAYER

Adjacent to the inner surface of the outer fleshy layer is a narrow but definite and conspicuous zone of dark, thickened fibers, 8-14 cells in width. In most sections the transition from the outer fleshy layer to the stony layer is abrupt, the appearance of which is accentuated by a slight separation of these tissues which occurred before or during preservation, by the nature of the cells of this outer fleshy layer which are frequently, but not always smaller adjacent to the stony layer, and by the dense appearance of the cells of the stony layer due to thickened walls and/or resinous contents. Not infrequently, however, the outer fibers of the stony layer are directed in such a way that they merge with the inner portion of the outer fleshy layer with no distinct line of separation.

The cells comprising the stony layer are longitudinally elongated, some 200-400μ in length. In transverse section they are more or less rounded or polygonal. The outer 5-6 rows of cells of this tissue are considerably larger than the innermost cells, averaging about 100μ in diameter. Beneath these rather uniform cells the underlying cells diminish in size rather abruptly to about 35-40μ in diameter for the innermost row. The walls of all the cells are about 3-6μ in thickness, though actual determination is difficult by reason of the nature of the cell contents and their present condition of preservation. All the cells are longitudinally directed but each cell may follow a tortuous course,

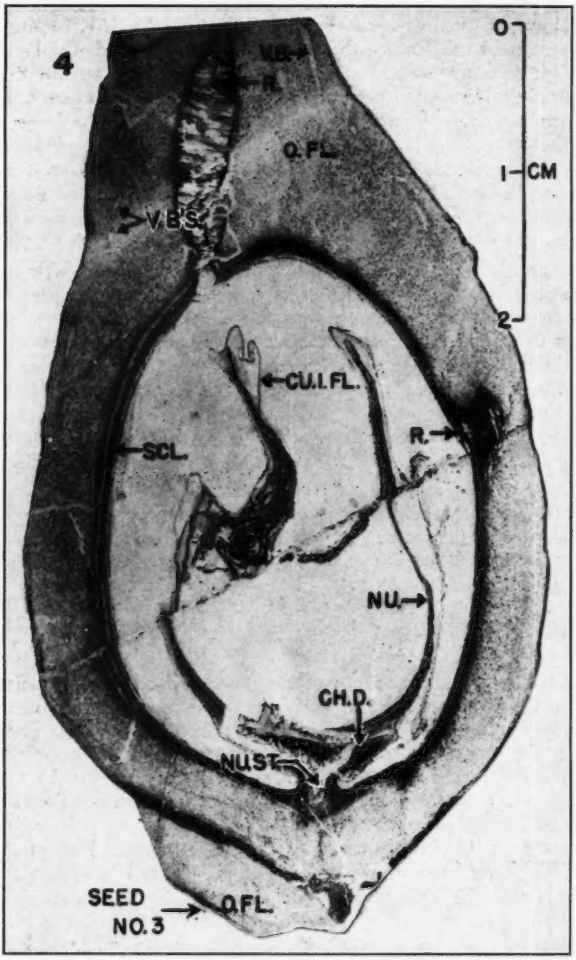

Fig. 4.—Longitudinal section of holotype showing the base in near-median section but missing the vascular bundle, and the apical end in tangential view, approximately 3 mm. from plane of base. A portion of the outer flesh (O.FL.) of Seed No. III is closely appressed at lower left. Lacunae of several vascular bundles (V.B'S.) are visible in the outer flesh. Parts of 2 of the 3 longitudinal ribs are visible. At right is an oblique section through one rib; at the top the rib is essentially transverse due to the extension of the longitudinal peel across the upper transverse face of the petrifaction. Peel-section 1807-F2.

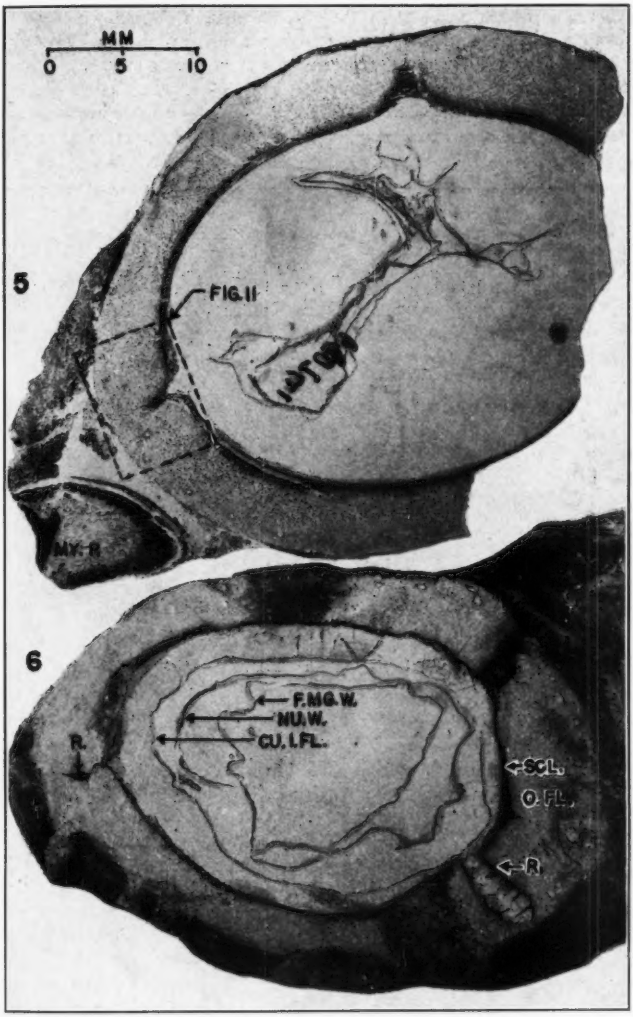

Fig. 5.—Obliquely transverse section through holotype. The 2 ribs (top and left) and the two extensions of the nucellus (top and bottom, left) are the same as those shown in fig. 4. Peel-section 1807-A1.

Fig. 6.—Near transverse section through Seed No. II showing the partially shrunken megaspore wall (F.MG.W.) and nucellus (NU.W.). The cuticle of the inner fleshy layer (CU.I.FL.) is shown as it is normally found, shrunken away from its original position just inside the stony layer (SCL.) of the integument. Peel-section 1807-E3.

often bending sharply so that in transverse section it is distinctly oblique. This interlaced condition is greatly accentuated in the micropylar area (fig. 17) and only a little less so in the chalazal area (fig. 8). Secretory elements were identified with difficulty in the stony layer.

Through the central portion of the seed this layer is rather uniform in thickness and measures about 400-500μ (figs. 9, 10, 13). It thickens notice-

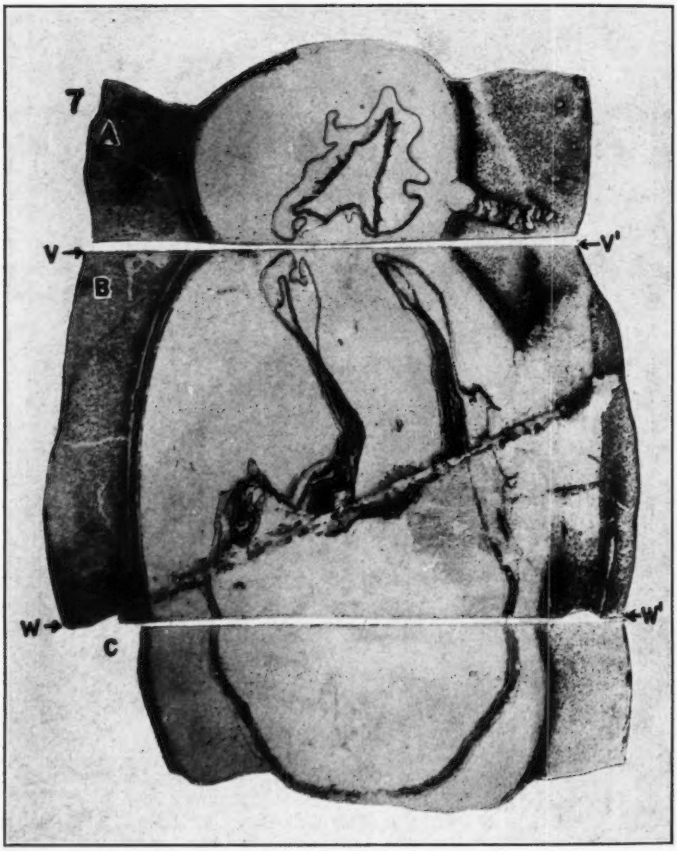

Fig. 7.—Composition showing a near-median longitudinal section, 7B, with 2 transverse sections, 7A and 7C, taken at levels of 1807-V7 (v-v') and -W5 (w-w') respectively. (See fig. 3). These show orientation of the radial ridges of the shrunken nucellus of such a section as shown in fig. 4. The nucellus is less distorted at the base. The vertical space in the integument on the right in 7B represents the lacuna of the rib shown in 7A. Peel-sections 1807-V7, -F13, and -W5. Scale same as in fig. 4.

ably above and below. At the base of the seed this tissue forms a clearly defined inverted cone which expands rapidly from the point of attachment of the seed to form the broad nucellus stalk and the peripheral layer of the chalazal disc (figs. 8, 14).

The outer surface of the stony layer is not uniformly smooth, but is conspicuously marked by radial extensions which form the characteristic ridges or "ribs," so typical of the internal casts of the Trigonocarpus type. The number of primary ribs extending from base to apex of the seed is 3 and a secondary rib much less strongly developed may occur occasionally between any two primary ribs. These are infrequent and of short vertical extent in the basal and lower portions, but in the micropylar area the stony layer increases unequally in thickness eventually forming 3 secondary ridges regularly alternating with the 3 primary ribs (figs. 21, 22, 18, 19, 20).

The 3 primary ribs vary considerably in their radial development. In general they are more strongly developed in the upper portion of the seed than in the central and lower portions. The ribs are often irregularly developed at the same level so that in a transverse section one rib may be seen extending entirely through the outer fleshy layer while one of the other ribs may not penetrate more than mid-way through the fleshy layer (figs. 5, 6, 11). In overall consideration, however, these radial extensions of the stony layer appear to form dehiscence lines which divide the integument into 3 essentially equal valves. Small isolated rib-like islands of stony tissue with lacunar central zones, infrequently occur near the periphery of the outer fleshy layer.

There is no essential distinction between the cells composing the ribs and the remainder of the stony layer. They are perhaps less tortuously intertwined, and the line separating them from the cells of the outer fleshy layer is less distinct than is normally observable between the two tissues. In transverse sections it is clearly seen that the ribs are not composed entirely of radial extensions of the stony tissue, but rather are commissured. Anastomising bands and plates of fibers form trabeculae which divide this lacunar area of the ribs into compartments. These vertically elongated trabeculae traverse the ribs usually in such a manner as to form irregular tangential plates. In most sections the spaces between the anastomosing strands appear to be devoid of cellular tissue, but frequently (fig. 21) areas of delicate parenchymatous tissue are seen. Whether this indicates a gradual loss of interstitial parenchyma as the seed matures or whether this tissue was lost before preservation cannot be determined. It is probable that parenchymatous tissue completely filled all of these areas in earlier stages of development. The secondary ribs are not commissured.

In many transverse sections it appears that a few trabeculae are diverted inward toward the nucellus (figs. 23, 36, 37, 7a, 7b, right hand side, 6). This situation was figured quite accurately by Brongniart (1881) in his pl. 17, fig. 8 and pl. 18, fig. 2, and copied with slight change of labels by Renault (1893, pl. 84, figs. 9 and 5 respectively).

Both Brongniart and Renault (1896) held erroneously that these trabecular strands joined the nucellus which would thus be held in place in the center of the seed by long thin plates. This is definitely a misinterpretation. Oliver (1902) basing his conclusions on the researches of Brongniart and Renault

elaborated this idea and prepared an illustration (text—fig. 5) in which he considered that the broad space between the stony layer and the inner epidermis of the integument was normally filled with a thick, weak, parenchymatous tissue which was not preserved, and that this space was, therefore, a natural structural feature. It is obvious that this broad space resulted from the shrinkage of the tissues internal to the stony layer before petrifaction. Oliver's hypothetical reconstruction of a transverse section through a seed of Pachytesta (1902, text—fig. 5) was unfortunate in that it has been widely reproduced and is unquestionably in error.

We can reproduce the essential features of Oliver's illustration in many sections. The radial extensions of the nucellus considered by Renault and Oliver to be definite in number and of structural significance are in all of our sections (figs. 7a, 5, 23, 35, 36, 37, etc.) indefinite in number and irregular in occurrence as is also seen in Brongniart's 1881 figures (pl. 17, fig. 5; pl. 18, fig. 2). These radial projections were never morphologically engaged with grooves of the inner layer of the integument for there is no doubt that they are merely the result of shrinkage and distortion of the nucellus before preservation.

The inward projecting trabecular plates of tissue of the primary ribs frequently appear, however, to follow to some extent the shrinkage pattern of the nucellus and epidermis of the inner fleshy layer. For a more correct interpretation of the organization of the seed of Pachytesta as seen in transverse section refer to figure 53.

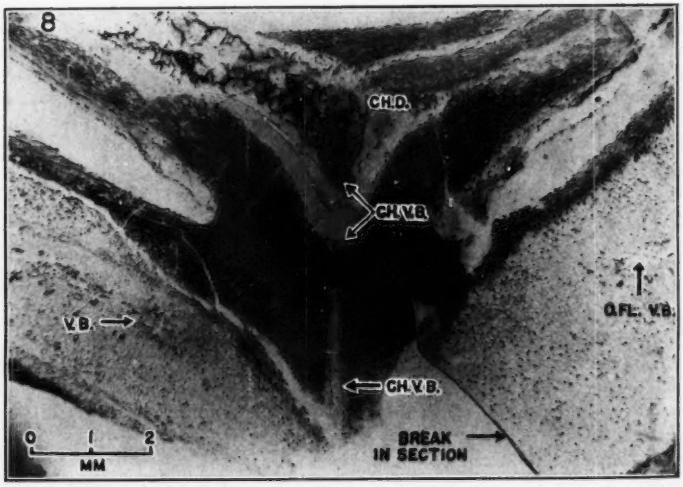

Fig. 8.—Median longitudinal section at base of seed showing the expansion of the nucellar stalk to form the chalazal disc (CH.D.), and the branching of the main vascular strand shortly after it enters the seed. Peel-section 1807-Ch2.

In the micropylar region where the diameter of the seed is greatly reduced the ribs, both primary and secondary, are in greater prominence. The primary ribs become enlarged radially, commensurate with the thickening of the outer fleshy layer thus giving in transverse section the characteristic "propeller" arrangement (figs. 1, 51). This prominence, which increases apically, is due to the fact that the ribs are not reduced in tangential thickness as the seed tapers. Thus they occupy a greater proportion of the area in relation to the outer fleshy layer than they do in the central region of the seed. The secondary ribs increase in both radial and tangential measurements apically and because of the reduced diameter of the seed at this level are laterally continuous with the primary ribs (figs. 19, 20, 21).

In the center of the upper one-fourth of the seed the area enclosed by the primary and secondary ribs is essentially triangular in transverse section (figs. 19, 20). A similar situation was figured by Salisbury for *Trigonocarpus shorensis* (1914, pl. 4, fig. 2) and by Scott and Maslen for *T. Parkinsoni* (1907, pl. 11, figs. 8, 7)where the strongly pronounced triangular area was erroneously considered to be the micropylar tube. This misconception was probably due to the lack of preservation of the inner fleshy layer which surrounds the micropylar opening in the specimens studied.

INNER FLESHY LAYER

A thin fleshy tissue lines the stony layer internally, extending continuously from the base of the nucellar stalk to the distal extremity of the integument. There is a considerable discrepancy in the literature regarding the presence and nature of this tissue. The problem arises from the fact that the inner fleshy layer was, at least in maturity, delicate and extremely thin except in the micropylar region. In most cases this parenchyma was more or less destroyed before petrifaction, so that the inner flesh is usually represented, especially throughout the central area of the petrified seed, only by the cuticle of its epidermis which faces the nucellar cavity. This membrane, furthermore, is usually found nearer to the nucellus than to the integument in plane sections and it follows more or less closely the nucellar outline (figs. 4, 6, 10, 14, 23).

In a few instances this cuticle is still in cellular contact with the integument (fig. 12). Occasionally it lies adjacent to the stony layer of the integument without the intervening parenchyma cells by reason of their disintegration prior to conditions favorable for preservation. We are able to trace this cuticular membrane from the base of the integument to the distal end of the micropyle without interruption. The orientation of this tissue is in all instances such as to indicate its affiliation with the integument and not the nucellus. The circumference of the internal cuticle of the integument is found to be very slightly less than the circumference of the inner border of the stony layer.

In many sections the epidermis or its cuticle is in juxtaposition with the outer epidermis of the nucellus. The cuticular membranes of these two tissues differ markedly in orientation, color, size, outline and extent of intercellular deposition (figs. 17a, 17b). Histologically, the cuticle of the epidermis of the inner fleshy layer is a bright golden-yellow, 1.75-2.5μ thick and resistant to maceration fluids. The ridges on its internal surface, which mark the former

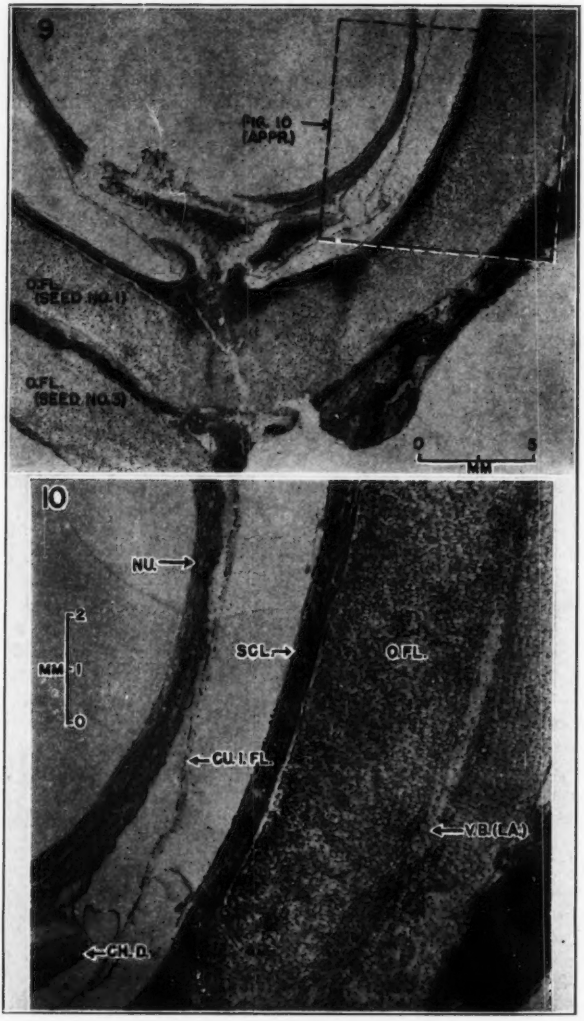

Fig. 9.—Base of seed showing chalazal disc. Secondary mineralization has distorted the tissues on the left. Peel-section 1807-F8.

Fig. 10.—Enlargement of another section from the position outlined in fig. 9. The vascular bundle (V.B.(LA.)) is represented here by peripheral "transfusion" tissue and a very few bundle elements. Peel-section 1807-F2.

outline of the epidermal cells, project inward about 2-4μ. At each angle of a former cell there is a slender internal projection of the cuticle about 20-38μ long, marking deposition in the intercellular spaces (fig. 17b). These fingers of cuticle occur in clusters of 2-5 at each angle. The length of these projections probably gives a fair conception of the radial diameter of the former epidermal cells which deposited them, i.e., about 30-40μ, and the tangential measurement, as indicated by the intercellular ridges of cutin, would be about 50-55μ.

Throughout the main body of the living seed it is probable that the inner fleshy layer was quite thin and delicate but certainly present. The nature of the cellular pattern figured by the cuticle precludes any possibility of its direct association with the innermost layer of stone cells. Most sclerotized tissues are surrounded by at least a few parenchymatous cells which are, if exposed, bounded by an epidermis. So a fundamental condition which might be anticipated is here obtained.

At the base of the seed the inner fleshy layer may be certainly identified. It is strongly developed in the micropylar region. Our material presents a structural arrangement of this tissue remarkably similar to that figured by Brongniart (1881, pl. 21, figs. 3, 4; pl. 20, fig. 3; pl. 18, fig. 2) and Renault (1893, pl. 83, figs. 5, 7, 8; pl. 84, fig. 1). They failed to recognize that the cuticle of the inner fleshy layer had been shrunken away from its former position. This led to erroneous conclusions as to the organization of the tissue of the inner part of the integument and of the nucellus.

MICROPYLE

At about the level of the pollen chamber the inner fleshy layer begins to thicken noticeably (figs. 34, 21, 20, 19) until, in the micropylar area, it is a wide tissue many cells in thickness. It fills the area bounded by the stony layer with the exception of the centrally situated micropylar tube. This opening is strongly defined (figs. 19, 20, 21, 34) by a cylindrical hypodermal zone of the inner fleshy layer, 3-6 cells in thickness. The cells of this delimiting tissue are firm, strongly walled and regularly arranged in radial rows (fig. 24). They give the appearance of a phellem.

The innermost layer of cells form a typical epidermis. The cells average about 33μ in radial diameter and about 25μ tangentially, which is slightly smaller than the cells comprising this tissue about the main body of the seed. Direct diameter measurements secured by averaging the longest and shortest diameter of the slightly elliptical opening at the level of peel-section R6, from which the picture in figure 24 was taken, average 920μ. If, however, the diameter is calculated from the average tangential diameter of the epidermal cells (25μ) and the total number of cells lining the tube at this level (104) a diameter of 827μ is indicated.

A heavy cuticle 8μ in thickness is continuous over the epidermis. Beneath the epidermis (peripherally, in relation to the integument) 3-6 rows of hypodermal cells, averaging 15μ in diameter radially and 25μ in diameter tangentially, with walls 2.5-4μ thick, may be seen. These cells together with the epidermis provide an effective tissue 80-120μ in thickness lining the micropyle. In addition to their thickened walls, many of the cells contain dense, dark contents similar to that found in secretory cells elsewhere.

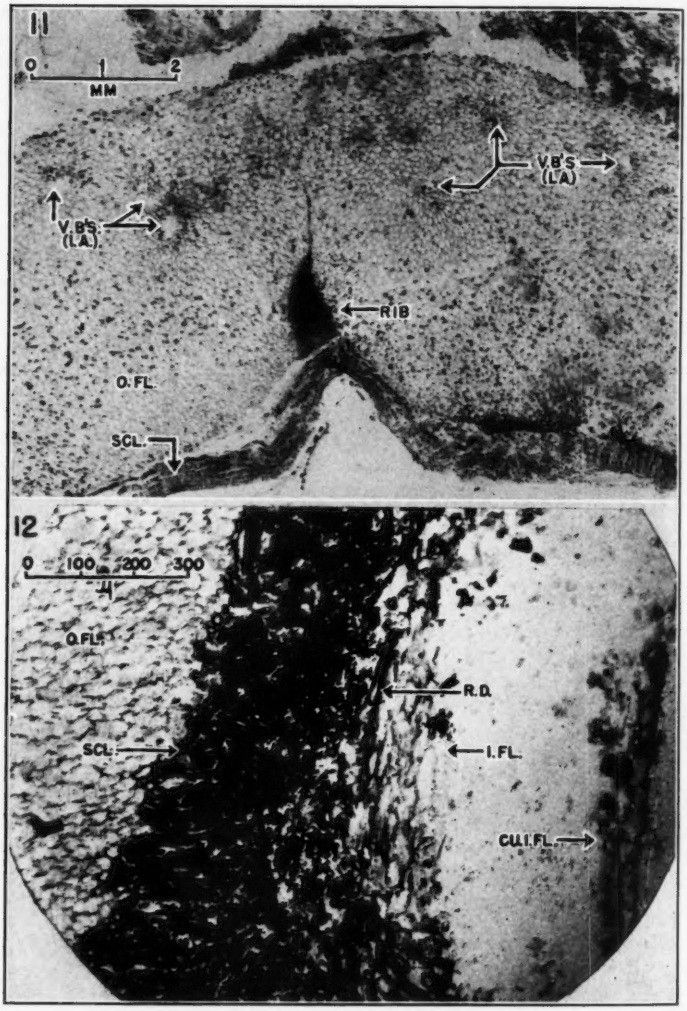

Fig. 11.—Enlargement of inset shown in fig. 5. Here the rib does not extend radially to the outside of the integument. The vascular bundles (V.B'S.(LA.)) nearest the ribs are more deeply placed in the outer fleshy layer (O.FL.) than the remainder of the bundles. Peel-section 1807-A1.

Fig. 12.—A portion of the integument showing the strongly developed stony layer (SCL.) surrounded by parenchyma of the outer fleshy layer (O.FL.) and bounded in-

The parenchyma of the inner fleshy layer surrounding this tissue varies from 12-15 cells in thickness, depending upon the position of the section observed (fig. 34). These cells differ considerably in size, the larger ones being about 125 by 75μ and the smaller ones almost isodiametric, 35 by 40μ. All are relatively thin walled, i.e., 0.75-1.75μ. Internally they grade in size, but not in thickness of cell walls into the cells of the hypodermis. In our specimen only a portion of the thick zone of delicate parenchyma cells of the inner flesh is preserved, but through serial sections its presence, extent and continuity are easily defined.

The diameter of the micropylar opening at the distal end is about 350μ. (Fig. 18 and fig. 17, the camera lucida drawing of most of that section, were taken at the level of peel-section T8, shown in figure 3. These are the most terminal cross-sections represented by any of our figures). The diameter of the micropylar opening increases slowly to about one millimeter at the level of the peel-section R32 (nearly mid-way down in the R-series, marked in fig. 3). Below this level it enlarges abruptly to about 1 cm. at the top of the nucellar dome. Attendant to this rapid increase in size the firm hypodermal cells of the inner flesh are reduced and finally disappear, and the total thickness of the inner fleshy layer diminishes to two or three cells. Figure 34 is a diagrammatic representation of this portion of the seed and shows the relationship of the inner flesh to the nucellus as it occurred in living state.

Nucellus

General Structure

The nucellus is attached to a broad, slightly concave, stalked disc which is an upward extension of the stony layer (figs. 4, 8). It is, therefore, entirely free from the integument. The nucellus is large, and no doubt in living state it was tightly appressed against the inner fleshy layer except, perhaps, at the base. It is barely possible that the space between the integument and the nucellus as seen in the fossil state represents the thickness of the inner fleshy tissue lost before preservation or in the development of the seed. It is probable, however, that it was produced by the shrinkage of the less firm nucellar tissue and contents before preservation. It appears reasonable to assume that the living nucellus was an ovoid structure about 2.5-3.5 cm. in size (fig. 3).

The stalk of the nucellus is 3.5 mm. in diameter and about 1 mm. long, expanding at its upper end to form the sturdy "chalazal disc" 2-3 mm. thick and 10 mm. across (fig. 8). This strong stalk appears to have held the nucellus aloft from the surrounding integument at the base. The lower (outer) layers of the tissue in the chalazal disc appear to have developed in such a way as to form a peripheral ring or collar of tissue (fig. 14). This is much less strongly developed than that described as an inflected mass of branching cells by Renault (1896, p. 390) for *Pachytesta incrassata* and *P. gigantea*.

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ternally by the thin inner flesh (I.FL.). A few cells of the inner fleshy layer are still attached to the cuticle (CU.I.FL.) which has pulled away. The increase in thickness of the stony layer below is due to its proximity to a main rib. Peel-section 1807-E3.

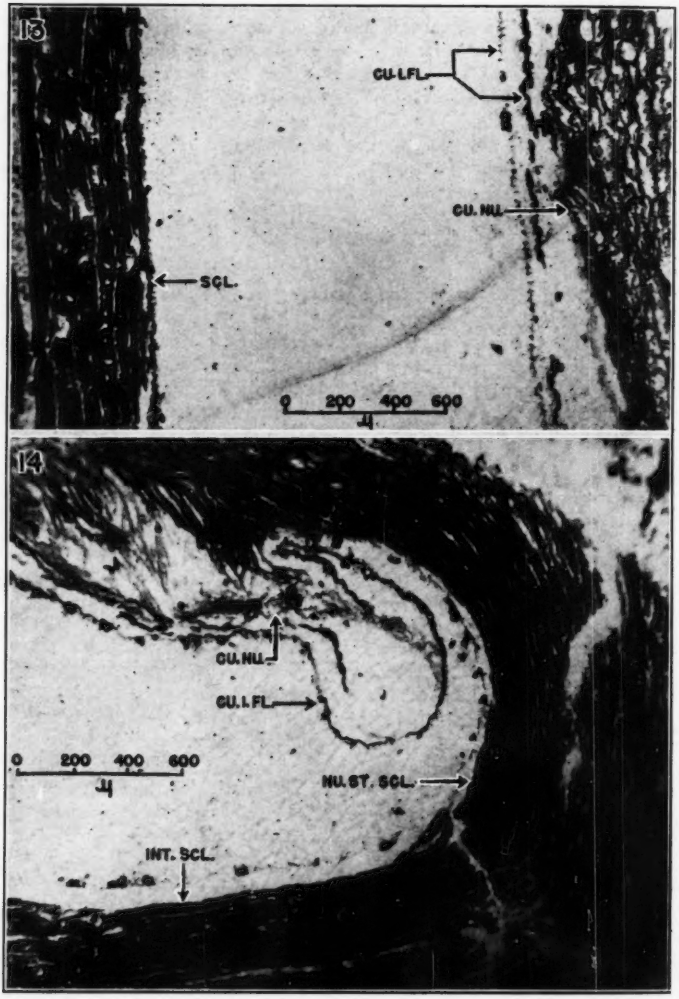

Fig. 13.—The most common arrangement of the inner tissues of the integument (SCL.) and of the nucellus is shown. The inner fleshy layer is mostly destroyed and its cuticle (CU.I.FL.) is pulled away and follows closely the wall of the nucellus. Peel-section 1807-F8.

Fig. 14.—This section of a portion of the stalk of the nucellus (NU.ST.SCL.) shows its relation to the stony layer of the integument (INT.SCL.) and to the scleren-

The wall of the nucellus near the place of attachment consists of three tissues, an outer parenchymatous layer, bounded externally by an epidermis with a well-defined cuticle, a central area made up largely of vascular tissue, and a narrow inner parenchymatous zone. This "wall" is, of course, merely the peripheral part of the nucellus remaining after the development of the functional megaspore which occupies most of the central portion of the nucellus. The wall tapers in thickness abruptly above the chalazal disc. From the level of peel-section X5 (fig. 30), which is approximately 600μ wide, it is reduced to about 250-300μ (figs. 9, 10), and toward the distal end becomes even much thinner (fig. 23).

A single vascular bundle enters the stalk of the nucellus and branches immediately in such a way that a vascular sheath is formed. Though this sheath is composed of individual strands, they are usually so close together that only a cell or two of parenchyma separates them, and often, too, the bundles overlap laterally. The bundles are discrete throughout most of their extent, but this is difficult to observe by reason of the overlapping or lateral juxtaposition already mentioned. They become more widely separated in the upper half of the nucellus and in our specimens were not observed in the upper 5 mm. of the nucellus wall. It is in this upper region that the nucellus wall appears as a very thin tissue 3-4 cells thick in the petrified state (fig. 23).

External to the vascular system is a peripheral zone of parenchyma cells bounded by an epidermis and its cuticle. This tissue is very irregular and was doubtless delicate for it is generally crushed and distorted. In figures 30 and 31 near the base of the seed, some idea of its general nature is discernable. There are 6-10 rows of cells varying greatly in size from 15-65μ in radial diameter. The total thickness of this layer in the mid-portion of the seed is generally less than 200μ.

The cuticle of the nucellar epidermis is thinner (1.5-1.7μ) than the cuticle of the inner flesh but the cells are larger. It is weakly pale-yellow to hyaline in color and membranous in texture. The intercellular deposits of cutin form distinct ridges 3-5μ high on the inner surface but there are no intercellular projections of cuticular residue as are so conspicuous on the opposing cuticle of the outer fleshy layer (fig. 17a). The epidermal cells themselves are large, varying from 115-175μ in greatest diameter, giving us another character by which to identify it.

The inner parenchymatous zone is variable in thickness and has no definite delimitation. In comparison with both the vascular zone and the outer parenchymatous zone, the inner parenchyma is very thin and may occasionally be missing.

The rounded, dome-like distal end of the nucellus is of particular interest. No vascular tissue extends this far and the wall is but two or three cells in thickness. The nucellar "beak," a special structure about 1 mm. in length, is

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chyma of the chalazal disc. The slight development of a peripheral collar of cells around the stalk is shown subtended (upper left). The orientation of the cuticle of the inner fleshy layer (CU.I.FL.) to the cuticle of the nucellus is evident. Peel-section 1807-F8.

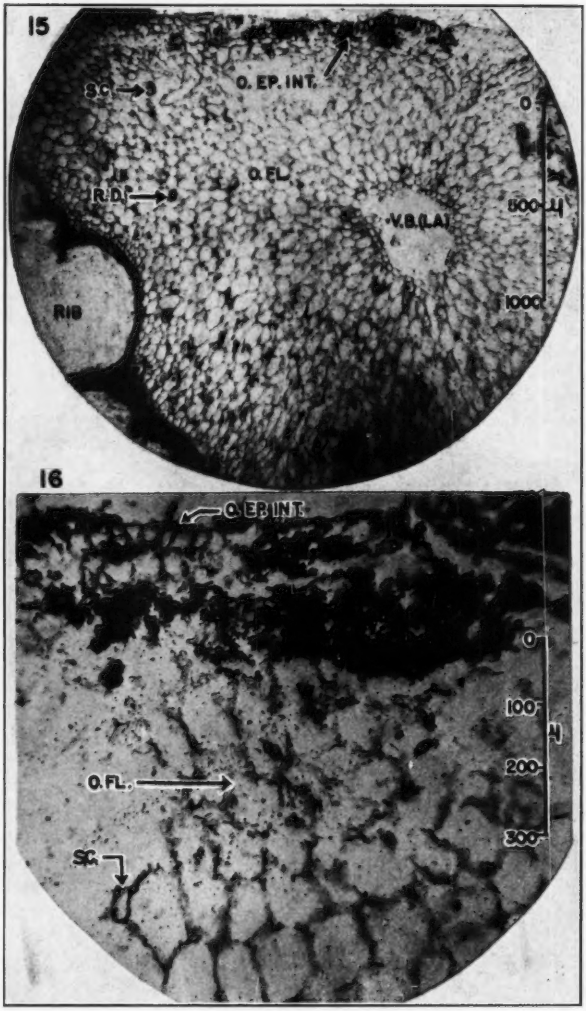


Fig. 15.—Portion of the outer fleshy layer of the integument showing the epidermis (O.EP.INT.). A number of secretory cells (S.C.) and resin ducts (R.D.) occur near the ribs and toward the periphery. Peel-section 1807-E3.

Fig. 16.—Another section showing the nature of the epidermis of the integument. Peel-section 1807-F5.

centrally located at the top of the nucellus and is, in reality, an opening into it. Since the nucellar beak extended for a short distance into the base of the micropylar tube in the living state (fig. 34), the effect is that of forming a continuous passageway through the micropylar tube into the nucellus. The opening through the nucellar beak is 175-190μ in diameter and is bounded by a single row of special cells with thickened walls, not unlike in appearance those epidermal cells of the inner flesh which surround the micropylar opening (fig. 38).

POLLEN CHAMBER

The area within the nucellus above the upper limits of the functional megaspore is the pollen chamber within which numerous pollen grains occur. In the preserved state, incident with the general shrinkage of the nucellus, the roof of the nucellus is partially collapsed. Figures 3 and 32 show this condition, with the roof sunken in and the nucellar beak tilted to one side of the saucer-shaped depression.

Thus in the ovular development up to the pollination stage the nucellus no doubt was closely pressed against the base of the micropylar opening. Modification and the disorganization of the tissues of the distal end resulted in an actual opening through the thin nucellar dome, so that at the time of fertilization there was no barrier between the tip of the micropylar opening and the functional megaspore such as that suggested by Salisbury (1914) for *Trigonocarpus shorensis*. Salisbury's diagram (1914, p. 42) indicates a pollen chamber within the nucellus beak, but with a "floor" formed from nucellar tissue. In our specimen there is no "floor" other than the megaspore itself. This may be but a matter of degree in the breakdown of the nucellar tissue prior to fertilization. Scott and Maslen (1907) state that "The megaspore wall was doubtless separated from the cavity of the pollen chamber by a transverse septum continuous with the nucellus," but admit that in the photomicrograph illustrating the pollen chamber that "the septum is wholly destroyed, unless the pad of tissue shown at *p*. (Scott and Maslen, 1907, pl. 12, fig. 13) has been displaced from the floor of the pollen chamber as is probably the case." The point to be remembered is that the pollen chamber is formed in or of the nucellus. There is no additional tissue which forms it, either in living Gymnosperms or fossil Pteridosperms. The pollen chamber is the product of nucellar modification during development and is probably a very different thing at different stages in the development of the ovule. An incomplete breakdown of the distal end of the nucellus may give a "floor" of nucellar tissue. Further modifications may remove this "floor."

Under any circumstance if we assume that pollen tubes were not present in this genus, and the available evidence supports this view, then we must also assume that the pollen may be carried to a position where a male gamete may reach the neck of an archegonium in the female gametophyte. It would not appear that this would be possible if the pollen grain or male gamete were separated from the megaspore by nucellar tissue unless we postulate an ultimate breakdown of the intervening tissue.

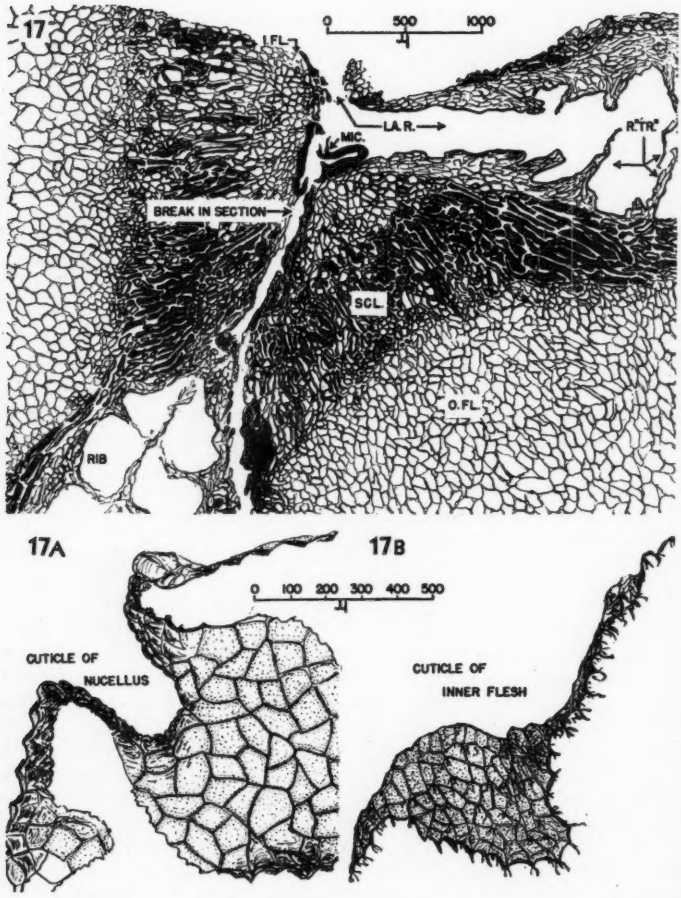


Fig. 17.—Camera lucida reconstruction from peel-sections 1807-T7, -T8, -T10, and -T12 of the area outlined by inset in fig. 18 illustrates the firm cuticle and reduced circumference of the micropylar opening (MIC.) and the lateral development of the stony layer of the integument (SCL.).

Figs. 17A, 17B.—Camera lucida drawings of portions of the cuticle of the nucellus from peel-sections 1807-VII and -F14, to be compared with the cuticle of the inner fleshy layer from the same sections. The larger cells and lack of inward projecting points of the nucellar cuticle are the most conspicuous differences discernible here.

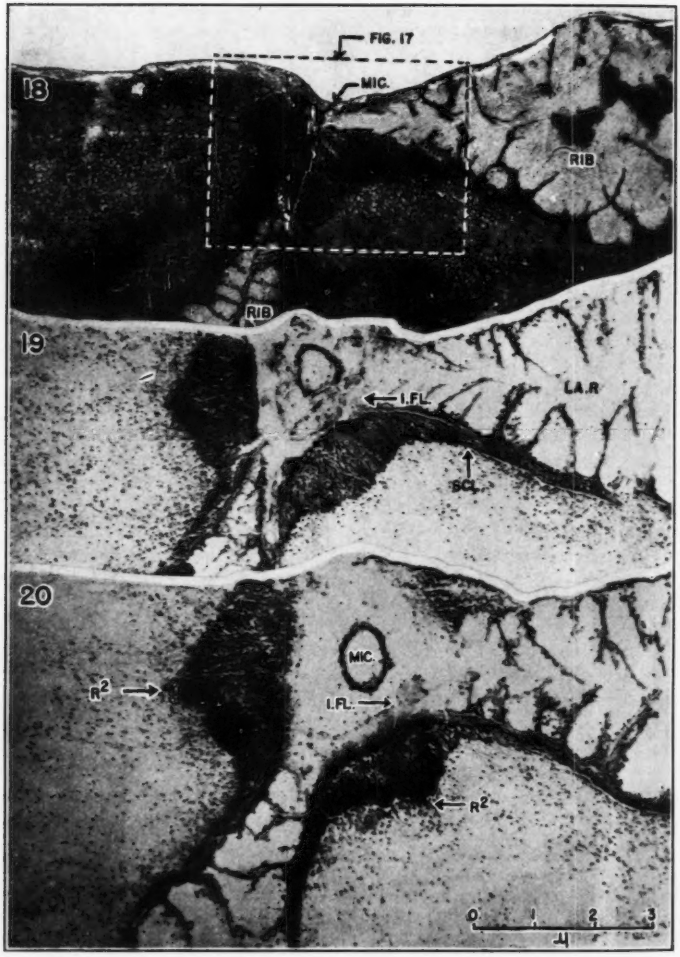
Vascular System

A single vascular strand enters the base of the seed from which one series of branches gives rise to an integumentary vascular system and a second series gives rise to a nucellar vascular system. This strand, the chalazal bundle, is strongly developed throughout its extent. It is best seen in figure 8 despite a break in that section and the mineralization which has disorganized the tissue in the upper part of the nucellar stalk. Below the break a continuous section of the bundle 3.5 mm. long is exposed, and above the break an additional 1.5 mm. may be seen. The total length is about 6 mm. from the point of entry at the base of the seed to its dispersal by branching to form the nucellar vascular system. It passes upward through the central portion of the inverted cone of mechanical tissue already described. A number of branches arising in close sequence in the lower 2 mm. supplies the integument. Figure 25 shows the nature of one of these branches in detail and an enlargement of a portion of the picture of this same area, figure 26, shows some of the histological features of the main strand. Here the chalazal bundle is 310μ wide just above the branch. There are 13-15 elements visible in most near-median longitudinal sections. The tracheids themselves range from 15-30μ in diameter and from 150 to about 500μ in length. They generally possess scalariform thickenings, frequently grading into reticulations. The bars of the scalariform tracheids average 2.5μ in vertical width, while the pits between the bars average 1μ. No protoxylem was identified. In other species it has been recorded as mesarch. Resin cells are occasionally present. These will be considered later.

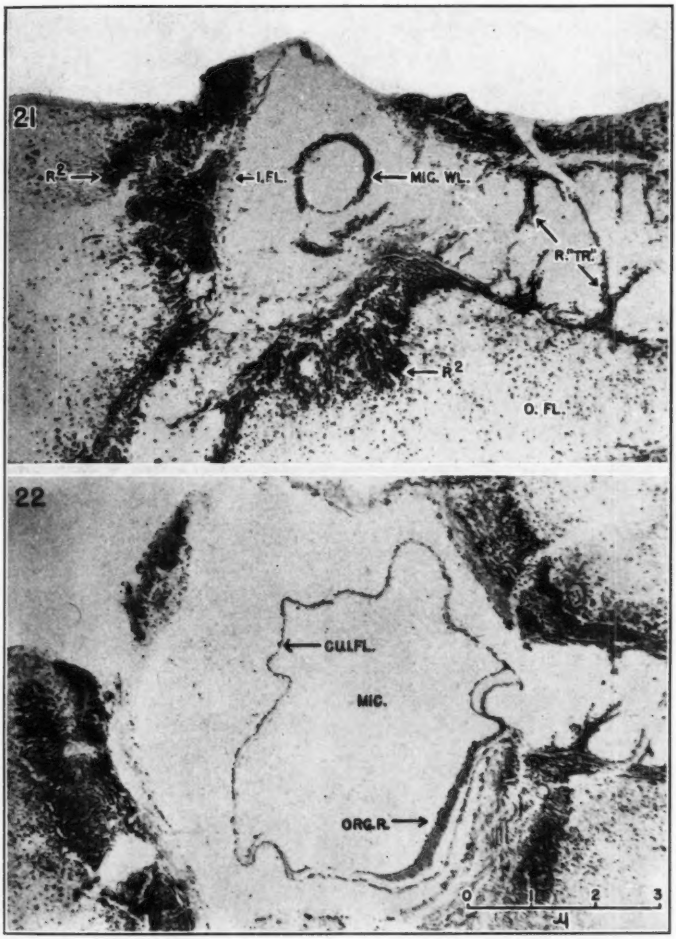
As we have seen above, the vascular bundles forming the integumentary system arise in a close series from the main chalazal strand. It is doubtful that these bundles again branch in the chalazal region (fig. 52). The position of the bundles immediately becomes established in the outer portion of the integument (fig. 56). The bundles are continuous essentially to the distal end of the seed. The number of vascular bundles seen in transverse section through the median portion of the seed is relatively large. In one series of sections 12 bundles occur in each of the three arcs of outer parenchyma between the major ribs, a total of 36 bundles (figs. 5, 6). This number is not constant, however, for some sections show more and others less. It is doubtful whether a definite number should be prescribed. Certainly as the seed narrows toward the distal end some of the bundles disappear, but even there the number is not less than 18 (fig. 1) in any section seen.

The bundles are arranged in a single row near the periphery of the outer fleshy layer of the integument with the exception that on either side of each major rib one or rarely two bundles are usually more deeply placed (fig. 11). There is some evidence that the inner bundles on either side of the major ribs arose by bifurcation of an adjacent peripheral bundle at some distance from the chalazal region.

The bundle arrangement of the integument, however, cannot be considered a "double" system, as is usually credited to the genus Pachytesta. In our material any single near-median longitudinal section through the base shows bundles being given off both to left and right within a short vertical distance, usually within less than 2 mm. Serial sections show conclusively that these



Figs. 18-22.—This series of transverse sections through the holotype shows the progressive changes in the various tissues from a level near the tip of the seed to a level approximately 2 mm. above the tip of the nucellus. All figures are of the same magnification. The interval between fig. 18 (peel-section 1807-T10) and fig. 19 (-S30) is 3.7 mm.; fig. 20 (-R4) is 2.4 mm. lower than fig. 19 and 2.4 mm. above fig. 21 (-R32). Fig. 22 showing a portion of peel-section -R57, 2.6 mm. below fig. 21, shows



vividly the relatively abrupt increase in size of the micropylar opening, the reduction of modified cells and cuticle of the inner fleshy layer surrounding this opening, and the relative reduction of the thickness of the stony layer. The secondary ribs (R2) show clearly in figs. 19-21 and the inner fleshy layer is relatively continuous in I.FL. in figs. 19 and 20.

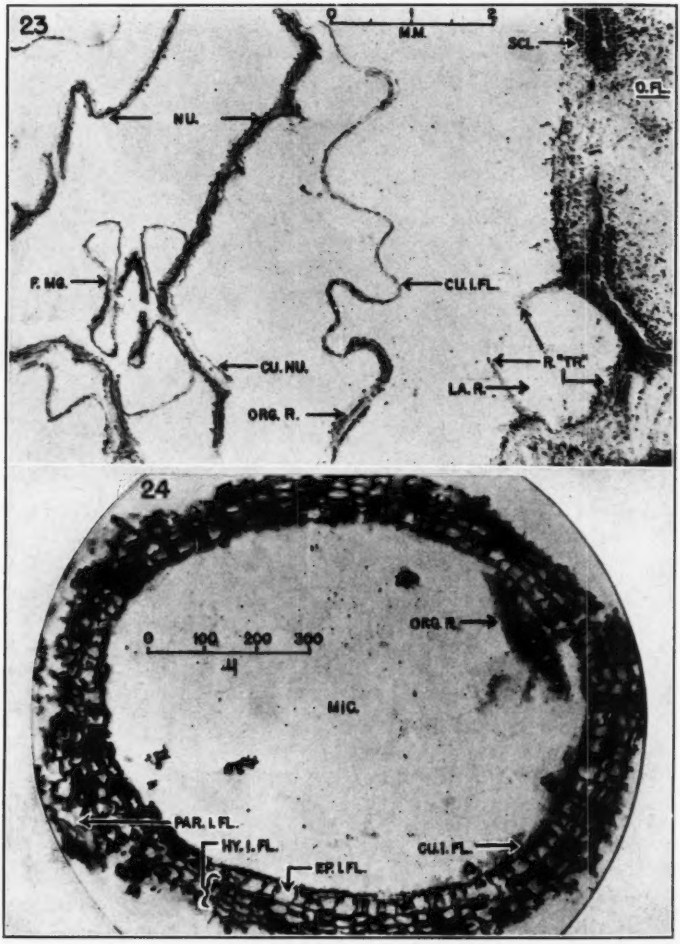


Fig. 23.—Section taken 3.5 mm. below the tip of the nucellus showing the convoluted appearance of the functional magaspore membrane (F.MG.) within the nucellus (NU.). The relationship of the inward directed ridges or plates of rib trabeculae (R."TR".) to certain folds of the cuticle of the inner fleshy layer (CU.I.FL.) which has pulled away from its original position may be seen. This section is about 5.5 mm. below that shown in fig. 22. Peel-section 1807-V15.

Fig. 24.—A more detailed view of the nature of the inner cells of the inner fleshy layer which surrounds the micropylar opening (MIC.) than that shown in fig. 20. Peel-section 1807-R6.

branches do not occur at any particular plane or planes, but rather arise indiscriminately about the main vascular strand within a short zone.

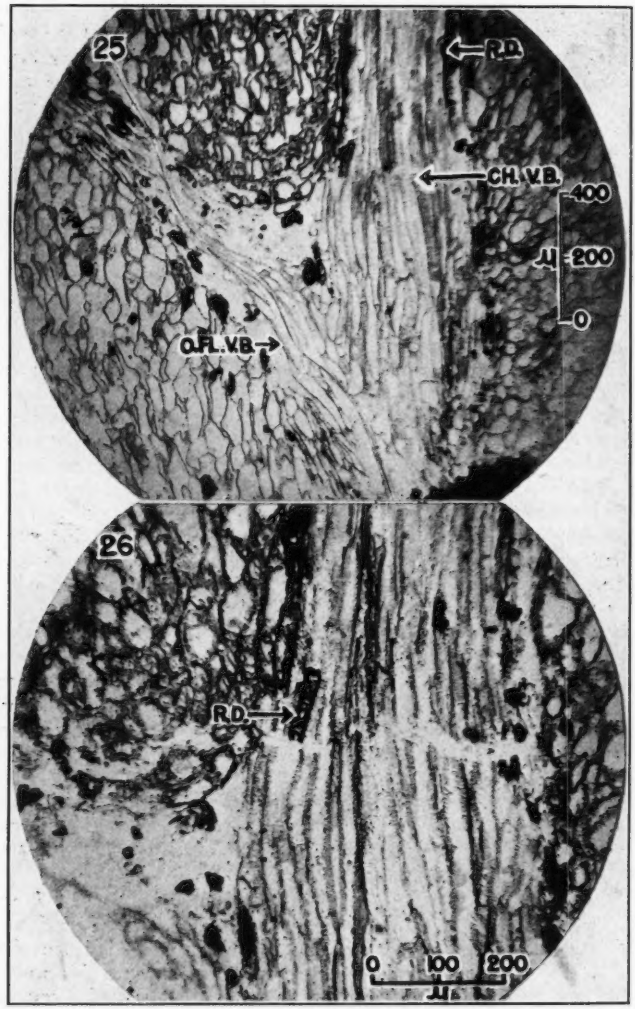
The apparent "two-level" origin of the bundles at the base of the seed as shown by Brongniart (1881, pl. 17, figs. 6, 7; pl. 19, fig. 2), and by Renault (1893, pl. 83, fig. 7) can be duplicated in several of our slides but the importance of any such prescribed points of origin is completely reduced by examining serial sections.

We have already mentioned that regardless of plane of origin these bundles soon become disposed in a single peripheral row in the outer layers of the integument (figs. 3, 8, 9). This situation is probably not fundamentally different from that described by Brongniart and Renault for *Pachytesta gigantea* and *P. incrassata*. Their figures are not altogether conclusive, but it should be noted that the one illustration (Renault, pl. 84, fig. 2) demonstrating a "double" system was taken from a section cut near the base of the seed. At this level our material also shows an irregular bundle arrangement as indicated above. It should be noted that figures of sections from the central region of the seeds (figs. 5, 8, pl. 17, Brongniart and figs. 5, 9, pl. 83, Renault) indicate a single peripheral row with occasional more centrally placed bundles. Generally these are adjacent to the major ribs, as in our material, but occasionally other lacunae are represented between the ribs. These latter may well represent the position of bundles, or they may be of uncertain origin (Renault, pl. 84, fig. 2). The total evidence does not support the view of a double vascular system in the integument throughout the main body of the seed of Pachytesta, but rather that these seeds possess a single peripheral row of bundles with such occasional irregularity as might be expected where large numbers of bundles are concerned.

The preservation of the vascular elements of the integumentary bundles is usually poor. In a few sections the entire bundle is present, in some, only a central strand of a few elements remains (fig. 27), and in the remainder, lacunae occur (fig. 28) with an average diameter of about 300μ. The lacunae are surrounded by a zone of cells transitional to the parenchyma of the outer flesh. This tissue (transfusion?) is composed of short, barrel-shaped, weakly pitted cells with an average diameter of 65μ, whereas that of the average cells of the surrounding parenchyma in the main body of the integument is about 80μ.

The general nature of these cells and the lacunae of the vascular bundles is evident in figures 27 and 28. The remaining tracheal elements of the bundle shown in figure 27 are about 21μ in diameter. Their measurements are in general the same as those given for the chalazal bundle.

The vascular system of the nucellus is derived from the complete dispersal of the chalazal bundle by its branching in the chalazal disc. As bundles pass radially they are so large and numerous as to form an almost continuous sheath at the base of the nucellus. As they pass outward and upward this mantle is resolved into discrete bundles which may be clearly distinguished in transverse sections. The bundles are flattened radially and throughout the entire lower portion of the seed, the lateral margins of each are separated from the adjacent bundles by only 1 or 2 parenchyma cells (figs. 30, 31). Often they overlap laterally. It is very difficult to determine any separation between bundles in longitudinal sections. The bundles extend to within about 5 mm. of the top



Figs. 25, 26.—A branch of the single vascular strand entering the base of the seed extends outward into the outer fleshy layer (O.FL.V.B.) while the main bundle (CH.V.B.) extends upward toward the chalazal disc. Peel-sections 1807-Ch3 and Ch2.

of the nucellus. They vary greatly in size, from 300-1000μ tangentially and from 150-300μ radially. Figure 31 shows a single bundle surrounded by parenchyma.

The bundles appear to be mesarch with the protoxylem located scarcely one-fourth the radial diameter of the bundle from its inner margin. These protoxylem (?) cells are usually crushed and no annular or spiral tracheids were identified. Outward from the protoxylem (?) are 6-10 rows of metaxylem, the cells averaging about 30μ in radial diameter; inward are only 2-3 tracheids averaging about 10μ in diameter (figs. 30, 31, taken at levels of X5 and X6 respectively). The scalariform thickenings are finer than those on the tracheids of the chalazal and integumentary bundles (fig. 29). The bars average 1.5μ in vertical width and the pits between the bars are about the same. They are nearly 15μ in longest dimension. No phloem was observed.

Secretory System

Special cells or ducts in several of the tissues contain dense, amorphous substances which appear to be resinous or gummy accumulations. The exact nature of these deposits is not known; they may be products of secretion. In our seeds these deposits appear to occur in several forms. The most conspicuous is the type of dark, possibly carbonized, substance occurring in long rods or partially filled, slender cylinders. Probably these are not greatly different in occurrence and organization from the mucilage ducts of cycads. They are elongated in an axial direction, many times their diameter (figs. 25, 26, 28). In the peel-sections it is common to find them 200-300μ in length with occasional rods continuous through 600-700μ. The longest measured was 1.1 mm., but longer specimens were observed by examining etched plane surfaces by reflected light and in thin sections. Their diameter varies considerably, ranging from 14-60μ for the smallest and largest measured. They appear to be inconstant in diameter throughout their lengths. For example one rodlet 450μ long, varied from 25-60μ. Occasionally the hollow rodlets contain thicker nodes of material which form pseudodiaphragms closely spaced and probably unrelated to the enclosing structure. It is possible that in some instances the rodlets represent the fillings of single, elongated cells or series of several cells placed end to end. In other cases they appear to be intercellular (schizogenous?). These latter are oftentimes very crooked.

In a very few instances a rodlet appears to be the filling or partial filling of a secretory canal or duct in that it is peripherally enclosed by a multicellular epithelium about 20-30μ wide. This type of duct closely compares with some which have been described for Medullosa (Schopf, 1939, p. 200, fig. 5). An excellent example of this type is seen in section T8, the rodlet of which is oval in outline and measures 84 by 50μ. The very thin-walled epithelium one cell wide measures 20μ in radial diameter, and the surrounding parenchyma is definitely organized about the entire duct.

Another form in which these deposits occur is in simple cells which are scarcely modified from the cells of the surrounding tissue. These are presumed to be secretory cells. Many of these are completely filled but often they are only partially filled in the petrified condition. In such a case the black or

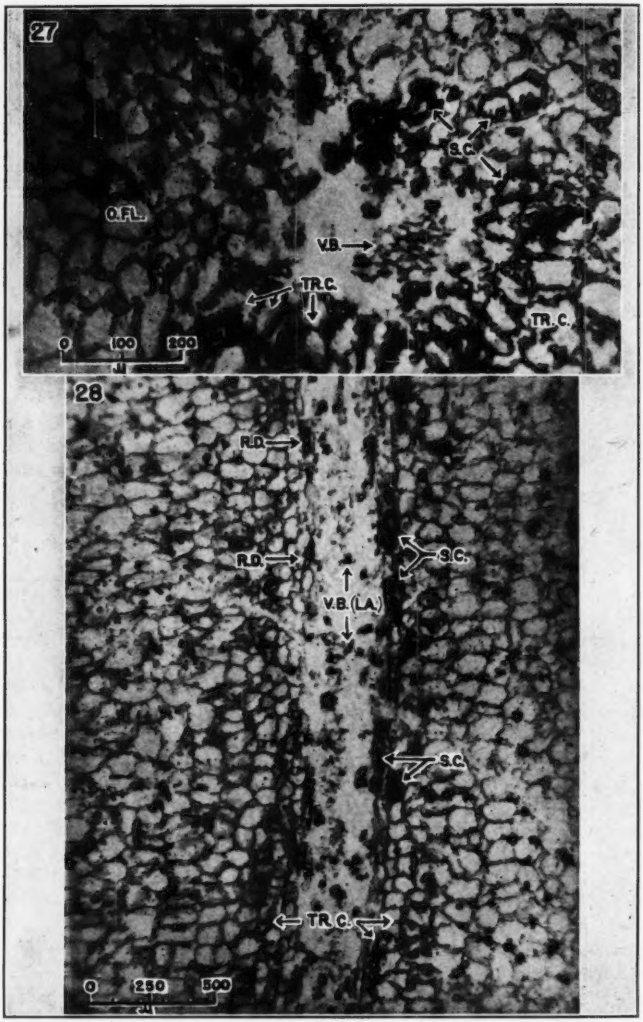


Fig. 27.—Nearly transverse section of a vascular bundle of the outer fleshy layer near the base of the seed showing surrounding transfusion(?) cells (TR.C.). Secretory cells (S.C.) are more numerous near the vascular bundles here than toward the upper end of the seed. Peel-section 1807-F8.

Fig. 28.—Longitudinal section through a vascular bundle of the integument at about the center of the seed. Many of the vascular elements are missing forming the lacuna (V.B.(LA.)), but at least a few tracheids may usually be found. Peel-section 1807-F8.

golden deposit is peripherally disposed and gives the cell the appearance of having a much thickened wall (figs. 15, 16, 27). Measurements conform closely to the size of the surrounding cells of the parenchyma tissue in which they occur. In the outer fleshy layer they average about 160 by 70 by 70μ in radial, tangential and vertical diameters.

Whatever the nature of these accessory deposits may be, they are widely distributed throughout the seed. According to distribution in the tissues they are most abundant in the outer fleshy layer, and sparsely present in the nucellus and stony layer. Regionally they are more numerous at the base of the seed, especially along the vascular bundles, and toward the outside and inside of the outer fleshy layer. They are also more numerous along the ribs. The rod or canal type of deposit occurs mostly in and near the vascular bundles of the outer flesh and chalazal region, and very rarely in the nucellus. The secretory cell type occurs irregularly throughout the parenchyma of the outer flesh, sparingly along the vascular bundles and is generally absent from the nucellus and stony layer. It might be suggested that many of the cells of the stony layer contain resinous contents. This is difficult to determine but it may be that the thick-walled cells of this layer and of even the smaller heavier-walled cells toward the tip of the seed in the outer flesh, contain accumulations of waste either as products of excretion or as peat-stage aggregation of humic materials.

Spores and Pollen Grains[3]

Megaspores

A close series of transverse sections was taken through the critical area of the micropylar region and the upper part of the nucellus. Approximately 140 serial sections in this area represent 12.65 mm. of the seed. Beginning with the first evidence of the apex of the nucellus, 21 serial peel-sections (fig. 3, U21-U1) which removed 1.65 mm. of material, a wire cut which destroyed 0.45 mm., and the first 8 peel-sections of the V-series which removed 0 37 mm., for a total vertical distance of 2.47 mm., brought the series of sections to the distal end of the large functional megaspore.

The megaspore membrane alone is preserved, although ample evidence of organic remains within it indicates the probability that at least some endosperm tissue had been destroyed prior to fossilization. The megaspore membrane is much shrunken and distorted in the petrified state, but in living condition it must have essentially filled the nucellar cavity.

The limited space above the functional megaspore membrane within the nucellus, a vertical distance of not more than 1.7 mm., represents the possible depth of the unspecialized pollen chamber. Serial sections through this pollen chamber disclosed not only numerous pollen grains, to be considered below, but also 8 groups of megaspores. These megaspores were, in most of the groups, arranged tetrahedrally, with the 4 spores somewhat separated one from

3 This section has been enlarged somewhat subsequent to its presentation before the General Section of the Botanical Society of America, St. Louis, Mo., March 28, 1946 (Hoskins and Cross, 1946).

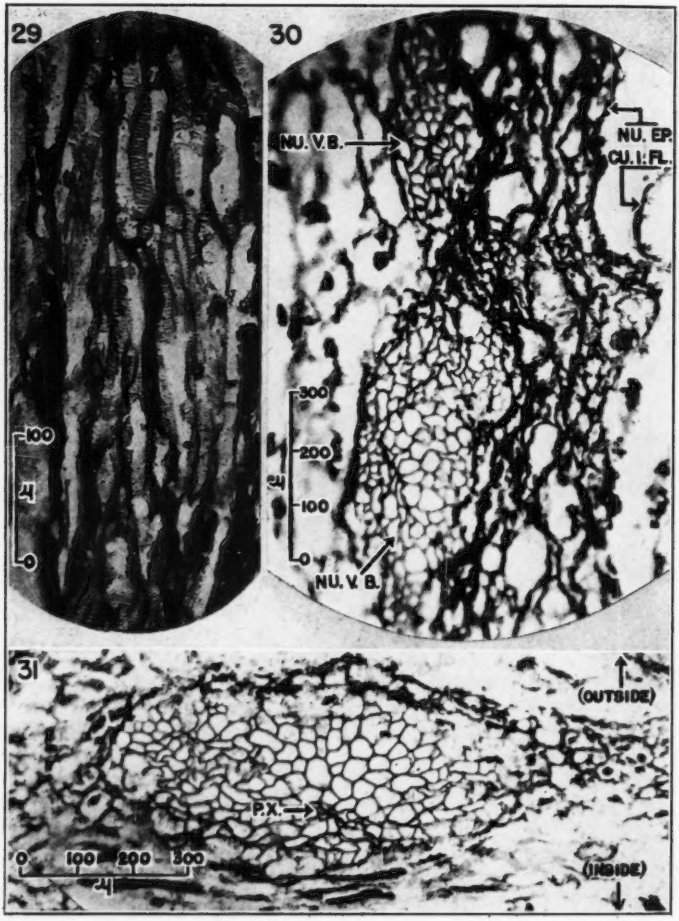


Fig. 29.—Longitudinal section of a vascular bundle from the periphery of the lower part of the nucellus. Peel-section 1807-F2.

Figs. 30, 31.—Transverse sections of parts of the periphery of the nucellus showing typical bundles which form a nearly continuous sheath. The proximity of the cuticle of the inner fleshy layer (CU.I.FL.) to the nucellar cuticle (NU.EP.) is the usual preservational condition. The protoxylem in fig. 31 is indicated at PX. Peel-sections 1807-X5 and -X6.

the other, yet preserving the characteristic tetrad arrangement. Measurements of the individual spores and of the tetrads indicate that the diameter of the spores was from 600-700μ, and that of a spore group up to 1400μ.

The walls of these non-functional megaspores are 7-10μ thick as compared with an average thickness of 15μ of the functional megaspore membrane. They are golden-yellow in color and strongly resistant to maceration fluids. The outer surface of the exine is granular to finely fibrillar, with pores or thinner zones of the wall averaging about 1μ in diameter. The internal surface is strongly reticulated with thickenings which anastomose in an irregular pattern, enclosing thin areas 7-15μ in diameter. The individual reticulation bars are 1.5μ wide and slightly thicker, perhaps as much as 2-3μ.

The wall of the functional megaspore is histologically similar to those of the non-functional megaspores except that the recticulations on the inner surface are not as prominent and the spaces between reticulations are slightly larger. The thickness varies from a maximum of 21μ at the upper end of the nucellus to as thin as 12μ below.

The size of these megaspores precludes their passage, even as individual spores, not only through the micropylar opening with its minimum diameter of about 350μ, but particularly through the nucellar "beak" or opening, which varies in different sections from 175-190μ in diameter. It is true that we do not know the dimensions of either the spores or tetrads immediately following reduction division, and it is probable that these spores increased in size to some extent after reduction, possibly indicated by the fact that each spore is slightly separated from the others in the tetrad. It can scarcely be considered, however, that the tetrads ever were small enough to pass through the micropylar and nucellar openings intact.

It must be remembered also that these are megaspores, not microspores or pollen grains, and it is difficult to postulate that tetrads of such spores normally would be dispersed. Further, there is no evidence of any break by which they could have entered the pollen chamber by any other means than through the micropylar and nucellar openings; this is precluded, as we have seen, by the size of the spores.

Since they occur in the logical position and as the histology of the wall of the functional and non-functional megaspore is similar, the evidence is convincing that several megaspore mother cells occurred in this ovule, that they underwent reduction division and the resultant tetrads were restricted to the distal portion of the nucellus by the normal enlargement of the single successful megaspore. The occurrence of more than one megaspore mother cell is not unknown among living Gymnosperms and the tetrahedral organization of megaspores has been reported.

Microspores and Pollen Grains

Abundant pollen grains of uniform type were found principally in the pollen chamber of Seed No. I. The only exception to this is the single well preserved specimen found in the micropyle (peel-section S24, fig. 45). No pollen or spores of any sort were found elsewhere in the seeds. Nearly 50

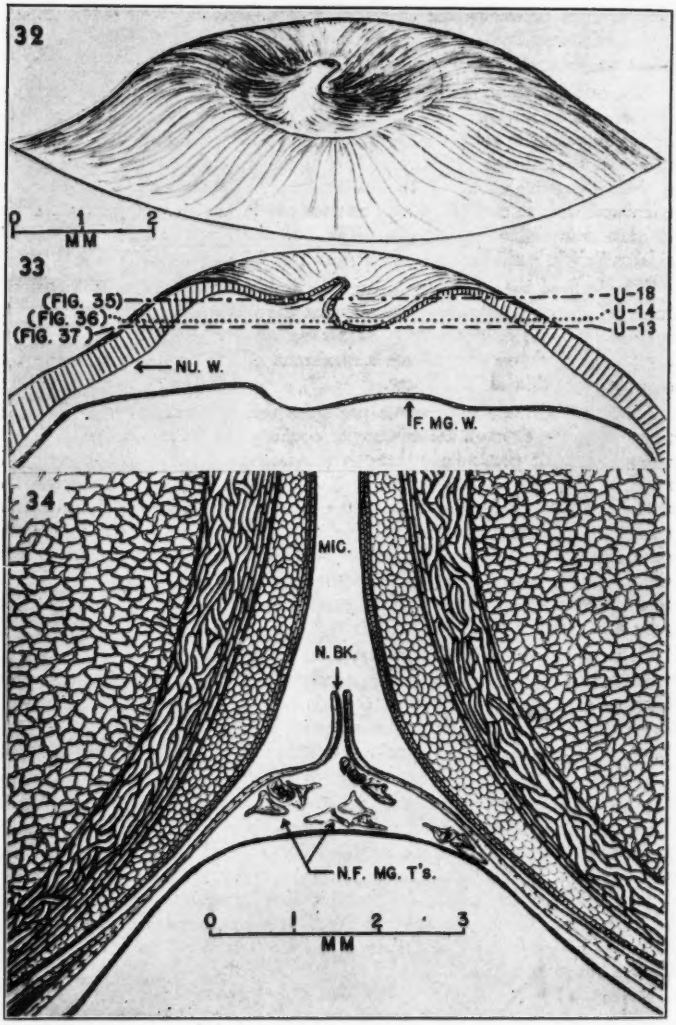


Fig. 32.—Diagrammatic representation of the upper end of the nucellus as found in the holotype. The nucellar beak is shown slightly to one side as a result of the collapse of the dome of the nucellus.

Fig. 33.—Longitudinal section through the same region showing the relative position of the upper end of the functional megaspore wall (F.MG.W.) to the top of the nucel-

pollen grains were seen in the peel series U20—U1, which represent progressively lower planes through 1.15 mm. of material beginning with the top of the nucellus roof. It is possible that additional specimens were lost in the portions ground away between peel-sections and perhaps, too, in the material lost in the wire cut between the U-series and the V-series below. No microfossils were found in any plane below this cut. In addition to these pollen grains and the 8 groups of megaspores previously discussed were found 3 well preserved and one fragment of triradiate spores of a form characteristic of the ferns (fig. 48).

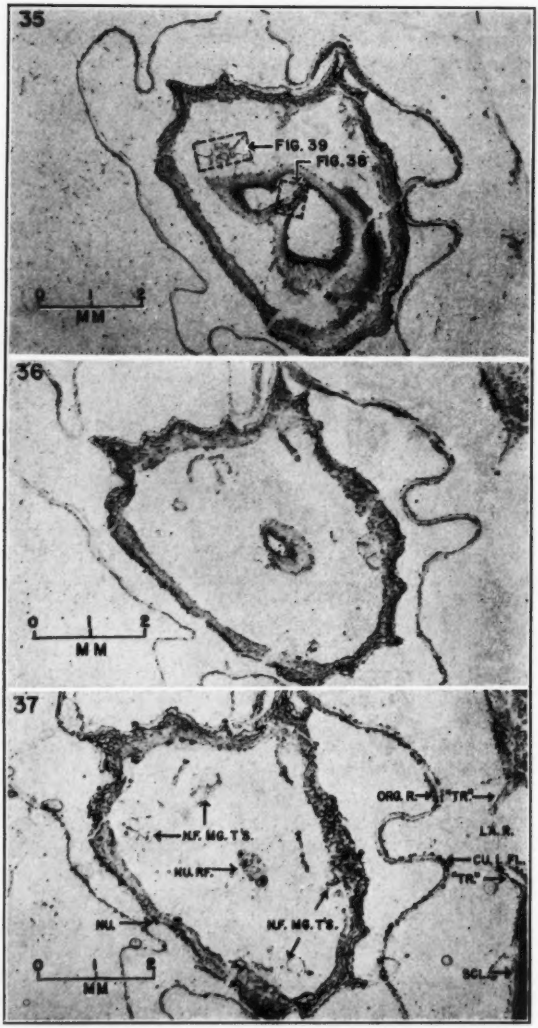
The pollen grains are relatively uniform in size and in ornamentation although they may appear to be different in various views. They are broadly elliptical in outline, averaging 63 by 45μ overall. The grains are bilaterally symmetrical, with an inflated peripheral bladder which appears to enclose intimately the central body except for a small distal area. The longest diameter of the annulate bladders of the spores measured ranges from 58-71μ, and the shortest diameter varies from 38-48μ. In end view (figs. 45, 46) the bladder appears to be about 25-27μ thick for uncompressed specimens. The central body is slightly longer than wide, parallel with the longest plane of the grain, averaging about 21 by 25μ, and about 21μ high (thick) in the axial plane (also discernable in fig. 45).

The surface ornamentation is conspicuous on the bladder but not on the central body. The outer surface of the bladder is smooth or very slightly pustulose. The inner surface bears a relatively strong reticulation with bars about 0.75μ wide and 1.25μ thick enclosing spaces about 3-5μ in diameter. The wall of the bladder is actually about 1.1μ thick exclusive of the thickness of the reticulations. The body wall is psilate and very thin. No haptotypic features, such as pores or a germinal furrow, can be identified. The wall is somewhat folded in most specimens but it is difficult to determine the extent of this phenomenon since inside of the central body a number of cells appear to have been formed. The differentation of the folds in the wall of the central body from the enclosed cell walls is not easily accomplished. No information concerning the nature of these cells could be obtained except that they lack contents and are exceedingly thin-walled.

The pollen grains thus described and figured appear to be congeneric with the material recently described from Iowa by Schopf (in Schopf, Wilson and Bentall, 1944) as Florinites. Our specimens appear to be somewhat smaller than his species, *F. antiquus* on the basis of measurements of 15 grains, and there is some distinction in the thickness of the internal reticulations. At the

lus (NU.W.). A portion of the intervening space in living condition formed the unspecialized pollen chamber. The dotted lines show the levels of peel-sections 1807-U13, -U14, and -U18, photographs of which are shown in figs. 37-35 respectively.

Fig. 34.—Diagrammatic reconstruction of a median longitudinal section through the upper part of the nucellus and the base of the micropyle. Four of the eight groups of non-functional megaspores (N.F.MG.T'S.) are shown in the relative position in which they were found. The thickness of the inner fleshy layer and the reduction in thickness of the nucellus wall should be noted.



Figs. 35-37.—A series of transverse sections through the region of the pollen chamber as shown in fig. 33. Because of the sunken roof of the nucellus the upper figure from peel-section 1807-U18 shows a hollow space above a portion of the roof (NU.RF.). The nucellus beak and part of the nucellus roof may be seen. Traces of the groups of non-functional megaspores (N.F.MG.T'S.) are evident. Associated pollen grains are too small to be distinguished. Peel-sections 1807-U18, -U14, -U13.

present time no attempt will be made to distinguish this material specifically from *Florinites antiquus* Schopf.

It is necessary to consider the possibility that these pollen grains are foreign to the seeds within which they have been found. We are aware of the potential occurrence of foreign pollen within pollen chambers as has been emphasized by Sahni (1915). Oliver's statement (1915) that it is reasonably safe to assume that plants growing in a natural habitat will have a preponderance of their own pollen, and that a preponderance of a single type of pollen grain alone is an evidence of natural relationship, is a sound, strong argument. In our specimen we have shown that the pollen grains were preponderantly of one type and that they occur in the most logical place, i.e., in the pollen chamber of the nucellus. We have shown beyond reasonable doubt that the tissues in that portion of the seed were intact at the time of fossilization.

Another evidence for establishing relationship of pollen found in any seed is to find adequate instances of its occurrence in seeds of the same type, or similar pollen in seeds with probable affinity. Such information would likely furnish sufficiently conclusive evidence of the natural relationships of pollen to seed. An analysis of numerous recorded occurrences of pollen grains in the seeds of certain radiospermic Pteridosperms, especially Pachytesta and Trigonocarpus, indicates that they have been found in only three species, *Pachytesta incrassata, P. gigantea,* and *Trigonocarpus pusillus.*

The available illustrations are few in number and apparently refer to the same material. Brongniart (1881) shows over 90 pollen grains in his plate 19, figure 1, and about 130 in plate 20, figure 2. Renault's illustration (1893, pl. 83, fig. 6) is remarkably similar to that of Brongniart (1881, pl. 19, fig. 1). These pollen grains are multicellular with a definite peripheral area (bladder?) and central body, and measure (by direct measurement of figures) between 30 and 40μ, certainly no more than 50μ. It is impossible to describe them accurately from the drawings. Renault's statement (1896) that they are of many types is not further elucidated nor substantiated with additional illustrations.

Saporta and Marion's review of this same material (1885, pp. 60-66 and fig. 21) has other illustrations of pollen grains from Pachytesta. Certainly, however, they must be in error on measurements, which they have accredited to Renault, when they give to their figured pollen grain of Pachytesta the diameter of one-half millimeter. It is scarcely probable that the figures of both Brongniart and Renault were only one-tenth the correct size. It is more likely that Saporta and Marion's statement should have been 50μ rather than 500μ for the diameter of the grain. This would be in keeping with the general size relationship determinable both by direct measurements and by comparison with the size of the opening of the nucellar beak and the cells of the surrounding tissues in the figures of Brongniart (1881) and of Renault (1893). The only other record for Pachytesta is the casual statement by Renault (1896, p. 392) that the large pollen chamber of *P. gigantea* contains pollen grains. Reed's specimens of Pachytesta (1939) do not show details of the micropylar region.

Brongniart's figure of *Trigonocarpus pusillus* (1874, pl. 22, fig. 2; recopied 1881, pl. B, fig. 2) purports to show pollen grains in the pollen chamber. Evidence of such occurrence is not conclusive from the drawings. He states

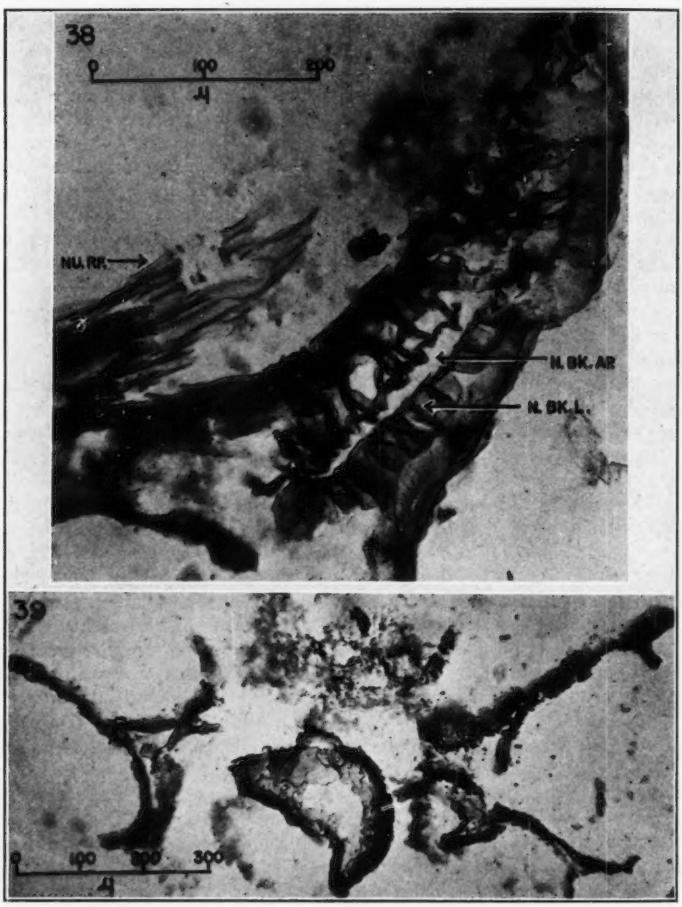


Fig. 38.—Obliquely longitudinal section through the nucellus beak shown in an inset of fig. 35. The beak is slightly flattened thus giving the aperture (N.BK.AP.) a slit-like appearance. The layer of modified cells lining this aperture is best seen in the lower central part of the picture. A portion of the wall of a non-functional megaspore is seen at the lower left as a dark, double-layered crescent. Peel-section 1807-U18.

Fig. 39.—Single tetrad of non-functional megaspores enlarged from an inset in fig. 35. Parts of three spores are represented by the main tissue remnants and the fourth spore is shown by serial sections to be present in the upper central area at a deeper level. Peel-section 1807-U18.

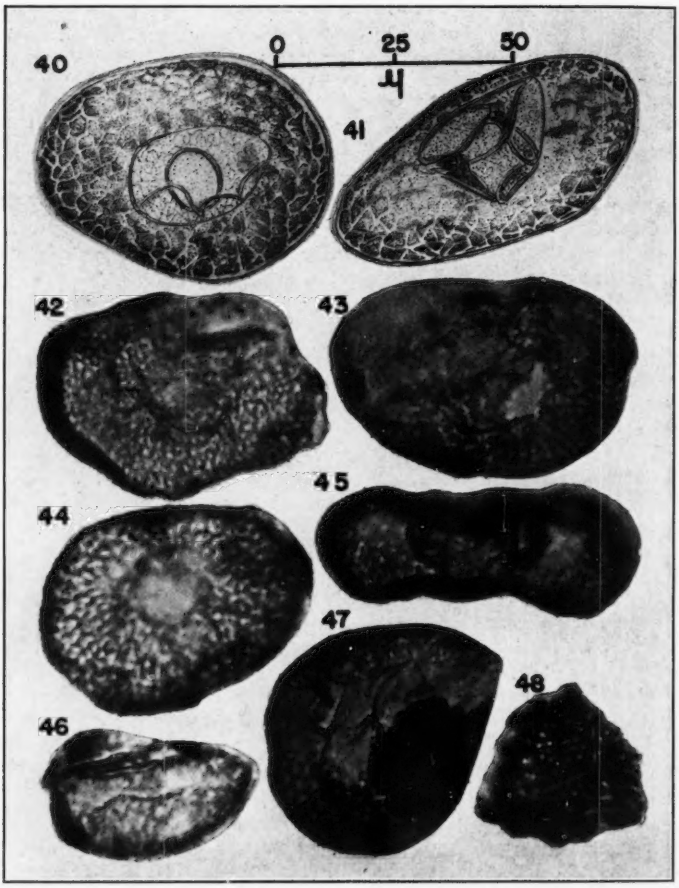
that the pollen chamber contains several pollen grains (1874, p. 252), and Renault (1896, p. 398) elaborates this statement only by adding that they were large, pluricellular, elliptical pollen grains. Oliver (1904b) found no pollen in his material of this species, and Krick's study of an American specimen (1932) gives no record of pollen. Hooker and Binney (1855) and Williamson (1877) do not discuss pollen in their accounts of Trigonocarpus. Scott and Maslen (1907) state that they found no pollen in *Trigonocarpus Parkinsoni* as does Salisbury for *T. shorensis* (1914).

Thus in the scanty imperfect record of occurence of pollen grains in seeds of this type we cannot doubt that some similarities exist between the pollen which is found in place in the apical end of the nucellus of our material and that which has been recorded heretofore.

It is necessary, however, to consider the problems in relationship arising from the available evidence. Florinites-type pollen has been studied in considerable detail by Florin in connection with his excellent researches on members of the Upper Paleozoic gymnospermic alliance. Its relationship to Cordaianthus of the Cordaitales, and to Lebachia, Ernestiodendron and Walchianthus of the Paleozoic Coniferales is postulated. Schopf concludes on the basic of the agreement in pollen structure that there is little doubt of relationship of these two great groups. His position is clearly stated (Schopf, Wilson and Bentall, 1944, p. 57) by "The pollen structure is so specialized, particularly when compared with the expression of spore characteristics elsewhere in the plant kingdom, as to permit no conclusion other than direct relationship. The possibility of convergent evolution being responsible for the structural similarity in the two instances is entirely remote." This is a strong statement. The determination of whether or not Florinites-type pollen is highly specialized or is a general type must be based on the breadth of its occurrence. The existence of this type of pollen in the Pteridosperms cannot be denied except on the grounds of inadequate physical evidence of its occurrence. The establishment of principles of evolution of pollen types and the consideration of relationships of plant groups possessing similar pollen, naturally must follow the extension of knowledge of pollen distribution rather than to predetermine it.

In the coal balls associated with the one which has yielded our specimens we find among the numerous plants present 2 or 3 distinct species of Cordaianthus. The pollen grains contained within these strobili are of a somewhat similar general type but are different in detailed anatomy. Some appear to belong to Florinites but others are more readily identifiable as Endosporites.

We are cognizant of the general association of the simple spores of the genus Monoletes (Ibrahim) S. W. and B. with the Medullosaceae (Halle, 1933, Schopf, Wilson and Bentall, 1944, et al.), within which the seeds Pachytesta and Trigonocarpus are no doubt properly included. But it is going too far, in our present state of knowledge, to assume that all the members of such a great group should conform in type of pollen or spores. The fact that a similar type has been assigned to both the Cordaitales and Coniferales does in no way preclude the possibility of the same general type developing here. On the basis of morphology, no objection can be sustained to the occurrence of



Figs. 40-47.—The only type of pollen grain found in the pollen chamber and micropyle is represented here in several views. Fig. 40 is a camera lucida drawing of a proximal view of a pollen grain from peel-section 1807-U18 showing the reticulation of the surface, the central body, and the central ring, possibly indicating the attachment of the bladder on the distal surface. Some of these features are clearer in fig. 41 (-U19) showing a pollen grain in another position. Figs. 42 and 43 are photographs of views corresponding to the drawings above them (-U18 and -U19). Fig. 44 (-U18) represents a distal view nearly opposite that shown in fig. 42. The pollen grain shown in axial view in fig. 45 (-S24) is the only grain found in the micropyle or outside the pollen chamber. Fig. 46 is an end view of a grain from -U16 and fig. 47 represents a pollen grain viewed at an angle so that its true length is not shown.

Fig. 48.—A photograph of one of the three triradiate spores found in association with the pollen grains. Peel-section 1807-U16.

pollen grains with a distended bladder in which the microspore has undergone some degree of germination before or shortly after dissemination.

Finally, then, on the basis of the purity of type, position of occurrence within the seed, general similarity to previously recorded occurrences in related seeds, and dissimilarity (generically?) to Cordaitean pollen which occurs in the same fossil deposit, it is not an illogical conclusion to suggest the affinity of these pollen grains to the seed in which they are found.

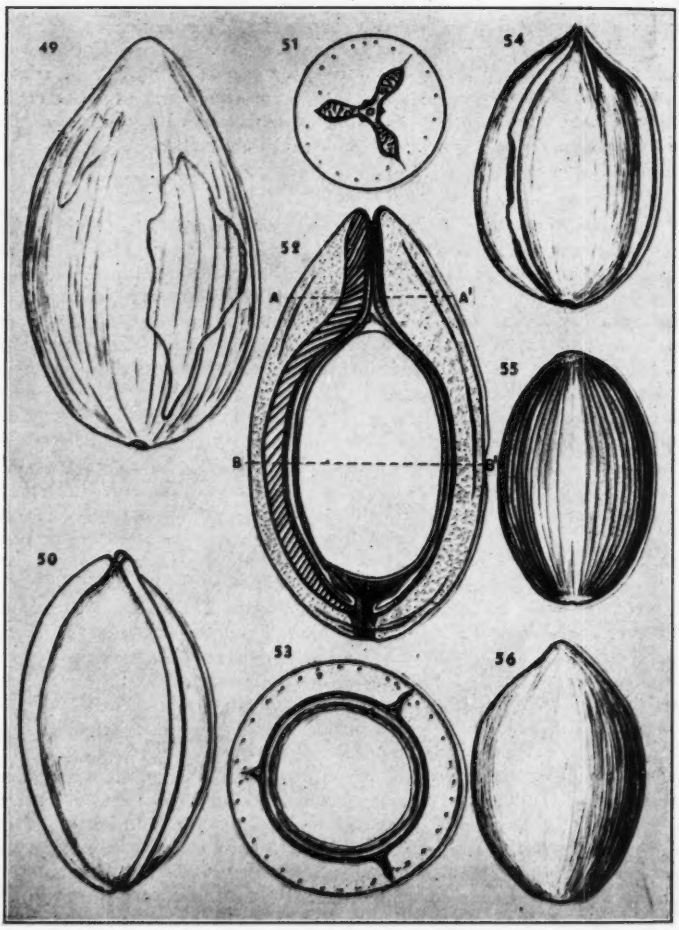
General Discussion

The genus Pachytesta was established by Brongniart (1874a, 1874b, 1881), for large seeds from the coal seams of France. It appears that Brongniart based his description on silicified seeds from St. Étienne, which he states had been designated *Rhabdocarpus giganteus* by Grand 'Eury. But he stated further that a study of the structure of the silicified seeds showed that they had nothing in common with that genus except superficial appearances. So for this type of petrified seed, which he knew in considerable anatomical detail from his researches, Brongniart introduced the genus Pachytesta with a brief generic diagnosis. He illustrated the species *P. incrassata* in plate 22, figure 4, below, and questionably in figure 4, above, and in figure 5. He introduced the species *P. gigantea* with a question mark (pl. 22, fig. 4, above), inferring difficulty in distinguishing between these two species. Unfortunately he failed to include specific diagnoses, but Renault (1896) does give a specific diagnosis of each.

Renault's description of *P. incrassata*, giving its measurements as 10-11 cm. long by 5-6 cm. wide, indicates that this seed was definitely larger than *P. gigantea* (described as 8-9 cm. in length and 3-4 cm. wide). This difference in size is probably not sufficiently decisive. The lack of satisfactory measurements of critical areas, the difficulty of determining such data from the figures, and the lack of comparable sections, make it difficult to differentiate between these two species on the basis of their original descriptions. For the present, however, we accept the validity of both species.

Brongniart's description of the genus, probably based principally on *P. incrassata*, includes the following basic characteristics: The seeds are large, ellipsoidal and attain a length of 11 cm. The testa (integument) is compact and probably very hard. It is about 6 mm. thick throughout the central area but increases in the chalazal and micropylar regions up to 12 mm. The tissue of the integument is composed of sinuous, elongated cells, bent in various directions depending upon the zone under observation. The integument is divided into 3 segments by sutures derived by the development of a thin layer of tissue. Each segment is attached to the nucellus by two ridges of tissue which appear to have been partially lost. Near the periphery of the integument are numerous vascular bundles. Some additional bundles, less in number, are further from the surface. They arise at different levels from the vascular bundle which traverses the base of the seed. The nucellus is elevated on a thick, short stalk topped by a concave disc. His illustrations show clearly a vascular system in the nucellus.

A review of the structure of the Iowa seeds described in considerable detail above indicates some features at variance both with Brongniart's material and with that of Reed (1939), who described parts of 2 seeds from Indiana as *P.*



Figs. 49-56.—Figs. 51 and 53 are transverse sections taken at the levels A-A′ and B-B′ in fig. 52. The arrangement and disposition of the principal tissues is clear. Fig. 52 is a diagrammatic reconstruction of a median longitudinal section through the seed of *Pachytesta vera*. A rib is indicated by the strongly hachured zone in the outer fleshy layer (left); the course of a vascular bundle through the outer fleshy layer is indicated by a discontinuous line near the periphery (right). Figs. 49, 50, 54, 55 and 56 show several fossil forms possible from this type of seed, as viewed externally, depending upon conditions of preservation. These forms will be considered in greater detail in Part II of this paper.

gigantea. In size (3.5 cm. by 6.5 cm.) our specimens are somewhat comparable to those of Reed's and are definitely smaller than either *P. incrassata* or *P. gigantea*. In outline and in relation of diameter to length, the Iowa specimens are more globose; and the micropyle occupies more of the overall length than in either *P. incrassata* or *P. gigantea*.

The evidence indicates that the total number of vascular bundles present in the outer fleshy layer, as seen in transverse section near the middle of the Iowa seeds, is apparently less than those of the 2 species from St. Étienne, though approximately the same or possibly more numerous than in Reed's Indiana specimens.

The Iowa seeds do not have a double vascular system in the outer fleshy layer as described and figured by Brongniart (1874b, 1881) and Renault (1893, 1896) for *P. incrassata* and *P. gigantea*. Renault's illustration of this feature for *P. gigantea* (1893, pl. 84, fig. 2), however, is taken from a section near the base of the seed and represents the position of the bundles shortly after their origin from the single chalazal strand. Figures taken more centrally in these seeds (Renault, 1893, pl. 83, fig. 5) fail to show this double system with the exception of an occasional lacuna internal to the peripheral ring of lacunae which mark the position of the vascular strands. We have given an explanation of this arrangement above (p. 231) and from that discussion have concluded that the vascular system of the outer fleshy layer is essentially a single one. Under any circumstances, there is no essential difference in the vascular organization of the outer fleshy layer of Brongniart's material and of our own. Reed's material appears to present the same situation (Reed, 1939, figs. 11, 14) but is not conclusive.

The point of greatest variance of our material from the generic diagnosis concerns the organization of the integument. We have considered above (pp. 215-217) and dismissed the possibility of an attachment of the integument to the nucellus as suggested by Brongniart and Renault, and figured by Oliver (1902, text-fig. 5). The Iowa specimens have a stony layer somewhat comparable to that described for *Trigonocarpus Parkinsoni* (Scott and Maslen, 1907), and for *T. shorensis* (Salisbury, 1914). Externally the stony layer is bounded by the outer flesh, a wide zone of fairly uniform, parenchymatous cells which become reduced in size in the outer 3 or 4 rows and is covered with a definite epidermis. This differs from the situation in *P. incrassata* and *P. gigantea* where the integument has both an inner and outer zone of thick-walled stone cells and where the cells of the tissue between these zones are not isodiametric nor as regular but appear to be somewhat elongate and sinuous.

An examination of Reed's material presents yet another situation. In her specimens the inner stony layer approaches the Trigonocarpus type and thus corresponds to the organization of this tissue in our seeds. But peripheral to this there is a rather thick zone of firm parenchyma which is not sinuous in the central region (cf. *P. incrassata*), but does contain numerous sclerotic patches. This layer grades insensibly outward into an irregular stony tissue many cells in thickness. This outer stony layer, which is absent in our specimens, is much thicker than in either *P. incrassata* or *P. gigantea*. In addition to this, there is externally a zone of firm parenchyma somewhat comparable in character to that internal to the outer stony layer. Thus her specimens show another varia-

tion of the histological organization of the integument of this genus. To what extent, if any, these variations may represent maturation stages we cannot suggest. It is interesting to note that in *Trigonocarpus shorensis*, Salisbury (1914) described the occurrence of numerous zones or plates of thick-walled cells in the outer part of the integument, while in *T. Parkinsoni* Brongn. and *T. pusillus* Brongn. such stony layers are absent. It is apparent, therefore, that no generic distinction should be based on this feature alone.

In view of the anatomy of the known species of Pachytesta we have no hesitation in placing the Iowa specimens in that genus.

Specific Diagnosis

Pachytesta vera Hoskins and Cross, sp. nov.

Organization.—Seeds large, radially symmetrical, ellipsoidal, 6.5 cm. long by 3.5 cm. in maximum diameter. Nucellus stalked and entirely free from the integument, occupying approximately three-quarters of the total length of the seed. Single vascular strand enters base of seed and branches to supply both integument and nucellus.

Integument.—Approximately 4.5 mm. thick throughout except in the micropylar area where it increases to 8 mm. Composed of a thick outer fleshy layer bounded by an epidermis with cuticle; a stony layer averaging 0.4-0.5 mm. thick except where radial extensions form three major longitudinal ribs extending from base to apex of seed, with occasional and irregularly placed secondary ribs; and a thin inner fleshy layer, except in micropylar area where it thickens greatly about the short micropylar tube. The inner fleshy layer is bounded by an epidermis with strongly developed cuticle.

Nucellus.—Bounded by an epidermis with cuticle; broadly dome-shaped at distal end, terminating in a short, centrally placed "beak" which projects into the base of the short micropylar tube. A definite opening, surrounded by special cells, provides a passage through the nucellar tissue to the unspecialized pollen chamber.

Vascular System.—Vascular bundles of the integument indefinite in number, varying from 18-36, extending from base to apex, arranged in a single series near the periphery of the integument; adjacent to each major rib bundles may be more deeply placed. Nucellar bundles arranged in a single series near the periphery of the nucellus, radially flattened and extended tangentially, crowded or even overlapping in basal area. Bundles extend to base of pollen chamber. Vascular tissue of both series composed of scalariform or occasionally reticulated tracheids; bundles probably mesarch.

Spores and Pollen Grains.—Single large functional megaspore essentially filling nucellus; non-functional megaspores, arranged tetrahedrally, in nucellus above functional megaspore membrane. Pollen of the Florinites-type, averaging 63 by 45μ in equatorial plane, occur in numbers within pollen chamber.

Locality and Horizon.—Upper Carboniferous, Des Moines Series, near Oskaloosa, Mashaska County, Iowa. Angus strip mine.

Material.—Two more or less complete specimens and a portion of a third in calcareous petrifaction No. 1807. Seeds sectioned to expose 19 surfaces from which about 400 peel-sections were prepared. Housed in Paleobotanical Collection, Department of Botany, University of Cincinnati.

Type.—Seed No. I, petrifaction (coal ball) No. 1807, designated as holotype.

ACKNOWLEDGMENTS

We wish to express our appreciation to Dr. Fredda D. Reed, Mt. Holyoke College, for making it possible to examine certain specimens of Pachytesta; to Dr. Theodor Just, the University of Notre Dame, for suggesting the specific name selected; and to Dr. Harry R. Muegel and Miss Jeannette M. Kryn, both of the University of Cincinnati, for reading certain sections of the manuscript and for assistance with the literature. A portion of this work was carried on while one of us (Cross) was a member of the Department of Biology, University of Notre Dame.

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ABBREVIATIONS AND DEFINITIONS APPEARING ON PLATES

BREAK IN SECTION	Specimen broken before peel-section made.
CH.D.	Chalazal disc.
CH.V.B.	Chalazal vascular bundle.
CU.I.FL.	Cuticle of inner fleshy layer.
CU.NU.	Cuticle of nucellus.
EP.I.FL.	Epidermis of inner fleshy layer.
F.MG.	Functional megaspore.
F.MG.W.	Functional megaspore membrane.
HY.I.FL.	Hypodermis of inner fleshy layer.
I.FL.	Inner fleshy layer.
(INSIDE)	Inner portion of tissue in relation to entire seed.
INT. SCL.	Stony layer.
LA.R.	Lacuna of rib.
MIC.	Micropyle.
MIC.WL.	Micropyle wall.
MY.P.	Myeloxylon petiole.
N.BK.	Nucellus beak.
N.BK.AP.	Nucellus beak aperture.
N.BK.L.	Nucellus beak lining.
N.F.MG.T'S.	Non-functional megaspore tetrads.
NU.	Nucellus.
NU.EP.	Epidermis of nucellus.
NU.RF.	Nucellus roof.
NU.ST.	Nucellus stalk.
NU.ST.SCL.	Sclerenchyma of nucellus stalk.
NU.V.B.	Vascular bundle of nucellus.
NU.W.	Nucellus wall.
O.EP.INT.	Outer epidermis of integument.
O.FL.	Outer fleshy layer.
O.FL.V.B.	Vascular bundle of outer fleshy layer.
ORG.R.	Organic residue.
(OUTSIDE)	Exterior or periphery of tissue in relation to entire seed.
PAR.I.FL.	Parenchyma of inner fleshy layer.
PX.	Protoxylem.
R.	Primary rib.
R2	Secondary rib.
R.D.	Resin duct, resin rodlet or resin canal.
RIB	Rib.
R."TR".	Rib trabecula.
S.C.	Secretory cell.
SCL.	Sclerenchyma.
SCL.CONE	Sclerenchyma cone at base of seed.
TR.C.	Transfusion cell.
"TR".	Rib trabecula.
V.B.	Vascular bundle.
V.B.(LA.). or V.B.'S(LA).	Lacunar area or areas resulting from partial deterioration of vascular elements of the bundle.
V.B'S.	Vascular bundles.

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Notes on the Anomalous Stem Structure of a Species of Bauhinia

Kenneth A. Wagner

Introduction

Several of the approximately 150 species of Bauhinia have been subjects for the investigation of anomalous stem structure. The material on which this study is based was collected in Honduras by Dr. T. G. Yuncker, James Koepper, and the writer during the summer of 1938,[16] and, being in a sterile condition, could be determined only to genus.

The writer is indebted to Dr. Carl LaRue of the University of Michigan, who reviewed and criticized this paper. Dr. LaRue suggests that this Bauhinia may be the same species as that which is called "Monkey Ladders" in Nicaragua. Dr. Paul Standley, in describing the flora of the Lancetilla Valley,[13] which is about 30 miles from where the material for this study was collected, lists two Bauhinias: one a small shrub, *B. divaricata* L., the other a woody vine, species not given. In his Flora of British Honduras[14] he lists four Bauhinias, one of which, *B. sericella* Standl., is a woody vine 15 meters long and provided with coiled tendrils.

Schenck (1893) lists three types of anomalous secondary growth as occurring in the genus Bauhinia: the formation of a cleft xylem mass; the formation of successively younger zones of xylem and phloem; winging and waving of the stem. The species studied here exhibits only the last mentioned type.

Eames and McDaniels state that all anomalous structures are due to either: 1) Cambium of normal type and persistence, by irregularity of activity, develops unusual arrangement and proportion of xylem and phloem or, 2) abnormal arrangement of cambium or formation of secondary layers of cambium.[4]

Kerner and Oliver in discussing *Rhynchosia phaseloides* show that injuries due to lateral pressure in the conducting tissue, especially in the soft bast, are prevented in climbing plants by the development of ribbon-shaped stems. The one year old stem exhibits normal growth, but during the second year, new cambiums arise at two points near the periphery of the stem.[9] Eames and McDaniels explain the formation of strap-like stems as due simply to the restriction of the activity of the cambium to certain areas.[4]

Stevens, in reference to Bauhinia, states that the ingrowth of pericycle cells and the production of secondary meristems in the wood parenchyma, medullary rays and even in the pith may result in the wood being cut up into many isolated strands.[15] Goebel believes that these new zones arise in the secondary phloem.[5]

Tsugio Handa, in describing the origin of the anomalous structures found in *B. Championi*, shows that two distinct types occur: 1) The vascular ring divides into several segments and secondary bundles are formed; cambial activ-

ity in the segments and secondary bundles eventually gives rise to a cleft xylem mass. 2) Secondary meristems originate in the pericyclic parenchyma and produce rings of wood and bast.[7] A somewhat similar situation occurs in *B. japonica*, also described by T. Handa.[6] In this case, however, it is noted that the central area of the stem is split up by the dilatation of the pith. In the parenchyma thus formed, several vascular bundles arise which soon become provided with a cambium. A second type of anomaly occurring in *B. japonica* is that in which the axial and periaxial woods become separated by the development of dilatation parenchyma between them. New vascular bundles arise in this area.

EXTERNAL STRUCTURE

The Bauhinia studied shows several o fthe characteristics of other tropical lianas. The stem is flattened and ribbon-like (see figure 1), showing varying degrees of S-shapedness according to age. The twisting of the stem is all in one or approximately one plane, and in cross-section, may appear flat or V-shaped, the latter being typical of more mature sections. Alternate, two-ranked tendrils arise from the middle of the flattened stem and on the convex side of the curvature.

INTERNAL STRUCTURE

A cross-section of a mature stem reveals many structures which would be expected, but there are also several variations from the usual pattern. The center of the stem is occupied by a cruciform pith. The orientation of the

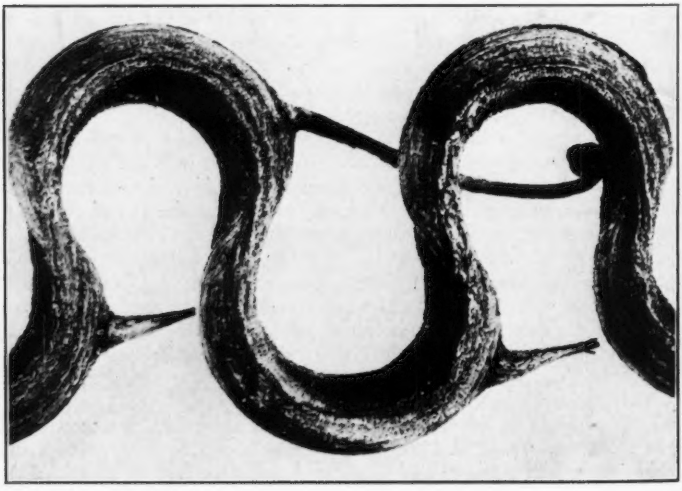

Fig. 1—Section of vine, 1×, with tendrils.

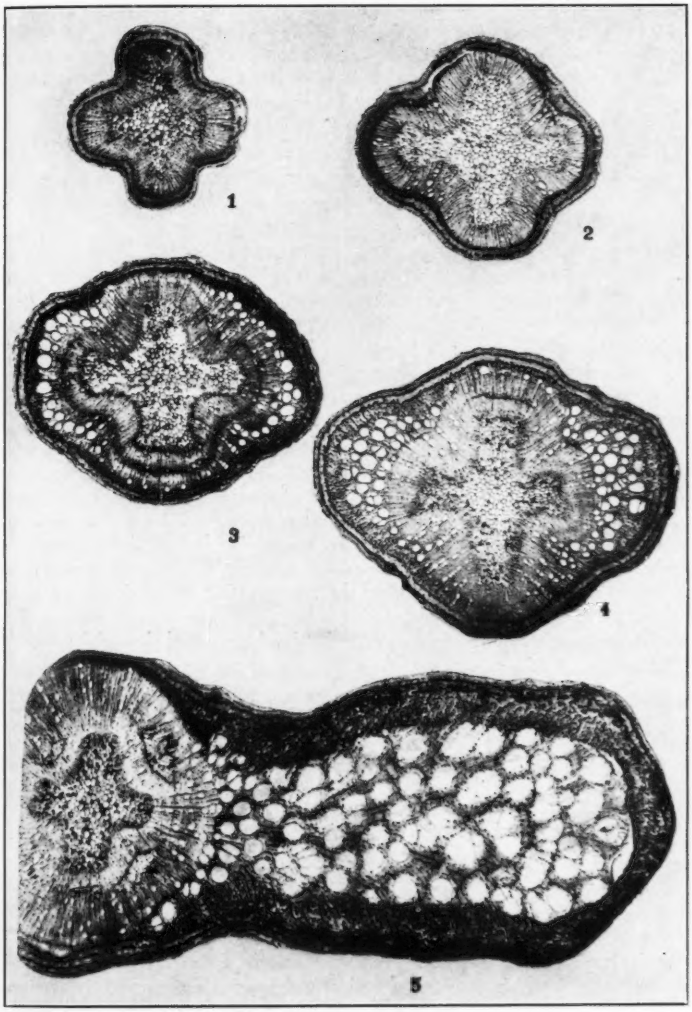

PLATE 1, figures 1-5. Cross sections of the stem showing successive stages of development, enlarged 12×.

arms of the pith is definite and consistent in reference to the formation of the expanded portions of the stem, which is usually referred to as the periaxial region or the wings. The pith is surrounded by a cylinder of xylem, the vessels of which are noticeably smaller and more consistently radial than those of the wings, as is well shown in figure 4. Isolated areas of parenchymatous tissue similar to the pith and corresponding to the previously mentioned dilatation parenchyma are found in this axial xylem (see figure 5).

The bark on the two non-expanded sides of the stem shows a development characteristic of most dicotyledonous stems in the early stages. The phloem of this area is very much compressed as compared with that of the wings, and is bordered by a narrow band of pericyclic parenchyma outside of which are found the usual pericyclic fibers. This sheath extends around the entire stem, but on the wings is composed mostly of stone cells, whereas the initial pericyclic sclerenchyma is entirely fibrous. The pericycle remains intact for a considerable time, being unbroken in the oldest material available for study.

The pith is differentiated from the promeristem in a cruciform pattern. One pair of arms, however, is usually narrower than the other, and may be slightly shorter. The wings are always formed adjacent to this shorter pair of pith arms. As the stem matures, the central portion of the pith becomes lignified and numerous simple pits are developed.

The protoxylem is differentiated in definite strands bordering on the edge of the pith. The smaller parenchyma cells between the protoxylem strands develop thick lignified walls. These cells, which constitute a layer three to seven cells deep, depending on the size of the protoxylem strand, have noticeably thicker walls than the subsequent wood parenchyma. The lateral development of vessels in the axial xylem during the first growing season is always on a radius extending from a protoxylem strand. Usually three growing seasons, i.e., rainy seasons, are required to complete the development of the axial xylem.

The secondary xylem in development follows the contours of the pith in early growth. As growth continues, the stem tends to become approximately circular in cross-section prior to the development of the periaxial region. In addition to the somewhat increased phloem production opposite the angle formed by the arms of the pith, two other factors contribute to the rounding out of the stem. One is the increased size of the vessels between the pith arms. This can be seen in figures 3 and 4. The vessels adjacent to the ends of the pith arms range from 15 microns to 33 microns in diameter, while those in between are 25 to 90 microns.

The third factor in this process of rounding out of the stem is the production of isolated areas of pith-like parenchyma in the xylem. This is well shown in figure 5 and is similar to the dilatation parenchyma discussed by T. Handa, but differs in that it is a direct product of the regular cambium. This cambial irregularity is of short duration and normal functioning is soon resumed, thus burying the parenchyma in the xylem. These areas are usually initiated when rapid growth starts at the beginning of a wet season. This parenchyma is similar to that of the pith, but the cells are more irregular in shape. The cell walls are similarly pitted, but the cells contain less of the inclusions found in the pith and other parenchyma tissue. While a few of

these parenchymatous areas, always very small, may be found opposite the ends of the pith arms, the larger areas are always in the angle formed by the arms.

The flattening of the stem by the development of lateral wings begins about the time the originally cruciform stem has become circular in cross section. Cambial activity on two opposite sides of the stem almost entirely ceases. The continued growth on the other sides produces the ribbon or strap-shaped stem.

The most striking feature of the periaxial xylem is the development of large vessels. These vessels vary in diameter from .075 mm to .352 mm, the average being about .234 mm. The length of the individual cells which compose the vessels, as determined by end wall indications, is approximately .360 mm. Perforation of the end walls is complete. The longest section of stem available for study was 114.5 cm. The vessels were continuous throughout the entire length of this section and probably extend indefinitely.

In the oldest stems available, the sclerenchymatous band of the pericycle was found intact and continuous. Accommodation to the expanding wings is accomplished by the derivation of stone cells from the pericyclic parenchyma. These stone cells fill up the gaps left in the pericyclic fibers as the expansion of the wings continues. Due to the limited expansion of the stem in the axial region, only a small number of these stone cells are found there. The sclerenchyma of the wings, however, eventually becomes almost entirely composed of stone cells.

SUMMARY AND CONCLUSIONS

1. The strap-shaped stem of this Bauhinia is the result of the restriction of the activity of the regular cambium to two localized regions on the periphery of the stem. The segmentation of the pith and wood as reported for other Bauhinias does not occur in this species.

2. The formation of the wings is always at right angles to the two-ranked alternate tendrils. There is also a consistent orientation relative to the position of the cruciform pith.

3. The periaxial vessels are unusually large in diameter, reaching .35 mm.

4. Continuity of the pericycle is maintained by the production of stone cells.

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